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OPERATOR-IN-TRAINING EXAMINATION STUDY GUIDE

PREPARED BY:

ONTARIO MUNICIPAL WATER ASSOCIATION & MINISTRY OF ENVIRONMENT AND ENERGY

For use by new operators preparing for the Operator-In-Training Examination as required under O.R. 435/93.

Ontario Municipal Water Association

Ministry of Environment and Energy
Ontario

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Additional copies of this guide may be obtained through the Certification Office of the Ministry, 905-456-0266 ext 332 or 305.

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ABOUT THIS STUDY GUIDE

This study guide provides background information to help you prepare to pass the Operator-In-Training (OIT) examination (information on becoming an Operator-In-Training and the Examination can be found in Appendix A). This guide is intended to familiarize new employees to terms and concepts which are common in the water/wastewater treatment industry. As such it is directed towards people with little or no exposure to the treatment industry. This guide is not a replacement for comprehensive training programs.

The study guide is broken into categories which roughly correspond to the sections of the "Need-To-Know" for the Operator-In-Training examination (a copy of the Need-To-Know is provided in Appendix B).

The study guide is applicable to all four Operator-In-Training examinations. For those parts which apply to any one examination, the code used to identify the exam is as follows:

ALL - All four exams
WT - Water Treatment
WD - Water Distribution
WWT - Wastewater Treatment
WWC - Wastewater Collection

Other more detailed study guides are available to help you prepare for future examinations. An abbreviated list of additional study materials for the OIT and Class 1 examinations is provided in Appendix C.

OVERVIEW (ALL)

As you prepare to write your Operator-In-Training examination you should be aware of the responsibilities being placed upon yourself when you become a qualified operator of water or wastewater facilities.

As a qualified water treatment and/or water distribution operator you will be responsible for the delivery of drinking water which is treated to a point where it will not endanger human health. In addition this water must also be delivered in quantities sufficient to handle fire flow requirements. Likewise, Wastewater Collection and Treatment Operators are responsible for the safe collection of sewage and for its treatment prior to its release to the natural environment. Consequently, all operators play a key role in public health and public safety.

Ontario owes much of its high standard of health to the water/wastewater industry. Without adequate treatment facilities diseases such as cholera, hepatitis, and dysentery would kill thousands of Ontarians every year. Non-treated or inadequately treated sewage would not only lead to human health problems but would also degrade our natural stream and lake ecosystems.

<u>OPERATOR LICENSING REGULATION (O. REG. 435/93)</u> (ALL)

Operators of domestic wastewater treatment and collection systems, and operators of water treatment and collection systems require a license to work in the Province of Ontario. This license will ensure that all operators have the required knowledge, experience and training to perform their duties. As an operator you should be familiar with the legislation, particularly those parts which set out the duties and responsibilities of operators. Until you pass the OIT exam and subsequently receive your OIT license you are not permitted to adjust a process, change flows or adjust chemical dosing unless directly supervised by a licensed operator. (Directly supervised meaning "over the shoulder" supervision.) If you are presently working in a facility which requires licensing you should discuss your duties, and the limitations to your operating activities, with your supervisor.

The Regulation divides the water/wastewater industry into 4 types: water treatment, water distribution, wastewater treatment and wastewater collection. In addition each type is divided into four classes (Classes 1-4) based upon the system's size and complexity (with Class 1 being the least complex). Each type and class of facility has a separate examination.

As you progress as an operator, you will be expected to pass a series of examinations to demonstrate your knowledge of water treatment, water distribution, wastewater collection or wastewater treatment. Your supervisor will be able to provide advice on which level of examinations you should work towards. To pass these examinations you must demonstrate abilities in mathematics, chemistry, biology, hydraulics, safety and public health. All exams consist of multiple choice questions.

BASIC & APPLIED MATHEMATICS (ALL)

Basic calculation skills are important for operators working in municipal systems. Operators must be able to calculate areas and volumes of reservoirs, lagoons, and cylindrical tanks. Dosage calculations and flow rates must also be determined. Operators should be familiar with both metric and Imperial units, and their conversions because equipment may be calibrated using either of these units.

This section provides a brief review of metric prefixes, conversions between metric and Imperial units, areas, and volumes. In order to understand these topics, the candidate must also be comfortable using the following basic arithmetic skills:

- Addition, subtraction, multiplication and division of:
  - whole numbers
  - fractions
  - decimals
  - percentages
- Expressing numbers in scientific notation
- Direct and inverse proportions

These skills are not reviewed in this manual. For further review of basic arithmetic, you may contact a local secondary school, community college or the Independent Learning Centre (See References, Appendix C).

METRIC SYSTEM

The Système International (SI) metric system is used throughout the world with the major exception of the United States where American (Imperial) units are common. Although, the metric system is used in Canada, operators will encounter equipment using both systems of measurement.

The table below gives some metric units for common quantities. Appropriate units for various quantities will be indicated in both the metric and Imperial systems in later sections.

Quantity	Metric Unit (Symbol)
Length	metre (m)
Area	square metre (m^2)
Volume	cubic metre (m^3)
	litre (L)
Velocity	metres per second (m/s)
Flow rate	cubic metres per second (m^3/s)
	litres per second (L/s)
	megalitres per day (ML/d)
Mass	gram (g)
Pressure	pascal (Pa)
Power	watt (W)

Prefixes are used in the metric system to indicate multiplication by a factor of 10. For example, the prefix kilo in kilometres indicates a multiplier of 1000; 34 kilometres is equivalent to 34 000 metres. In general, numbers should be kept within the range of 0.1 to 1000. Prefixes can be used with the units to allow numbers within this range. Some commonly used prefixes are listed in the following table.

Prefix	Symbol	Multiplier	Some Basic Conversions
nano	n	10^{-9} = 0.000 000 001	1 m^3 = 1 000 L
micro	µ	10^{-6} = 0.000 001	1 L = 1 000 mL
milli	m	10^{-3} = 0.001	1 kg = 1 000 g
centi	c	10^{-2} = 0.01	1 g = 1 000 mg
deci	d	10^{-1} = 0.1	1 d = 24 hr
kilo	k	10^{3} = 1 000	1 d = 1 440 min
mega	M	10^{6} = 1 000 000	1 d = 86 400 s
giga	G	10^{9} = 1 000 000 000	1 mg/L = 1 kg/1 000 m^3

UNIT CONVERSIONS

Unit cancellation is one of the best ways to make sure that conversions are done correctly. The appropriate units are written next to each number and multiplied, divided, and "cancelled out" just like numbers in arithmetic operations. The factors used to convert from metric to Imperial units in these examples (for instance 3.281 in example 1 below) are taken from the aid sheet provided during the certification examinations (see Appendix D). The following examples will illustrate the process:

Example 1: Convert 13 metres to an equivalent length expressed in feet.

$$13 \text{ metres} \times \frac{3.281 \text{ feet}}{\text{metres}} = \frac{42.653 \cancel{\text{metres}} \times \text{feet}}{\cancel{\text{metres}}} = 43 \text{ feet (rounded)}$$

Example 2: Convert 960 cubic metres per day to an equivalent flow rate in cubic metres per second.

$$\frac{960 \text{ m}^3}{\cancel{\text{d}}} \times \frac{\cancel{\text{min}}}{60 \text{ s}} \times \frac{\cancel{\text{h}}}{60 \cancel{\text{min}}} \times \frac{\cancel{\text{d}}}{24 \cancel{\text{h}}} = 0.011 \text{ m}^3\text{/s (rounded)}$$

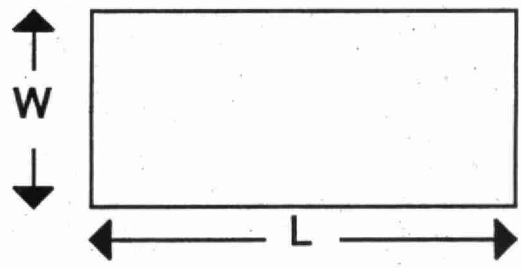
AREA

The area of a figure is the surface enclosed within the lines of the figure. Area is measured in square units. Some metric units for measuring area are: m^2 or cm^2. Some Imperial units for area are: in^2 and ft^2. An aid sheet giving the formulas used in calculating the area of several common shapes is provided during the OIT examination. A copy of this aid sheet is included in Appendix E. When using these formulas, it is important to ensure that all of the measurements are in the same units.

RECTANGLES

A rectangle is a four-sided figure which has opposite sides that are parallel and equal in length. Each of the four angles within a rectangle is 90°. The area of a rectangle is length multiplied by width.

Area = L x W
L = length of rectangle
W = width of rectangle



Example: Find the floor area (m^2) in a rectangular room with a length of 7 metres (m) and a width of 400 centimetres (cm).

Solution:

(1) Convert measurements to the same units

$$L = 7 \text{ m}$$

$$W = 400 \text{ ~~cm~~} \times \frac{1 \text{ m}}{100 \text{ ~~cm~~}}$$

$$= 4 \text{ m}$$

(2) Enter values of length and width in formula

$$\text{Area} = L \times W$$

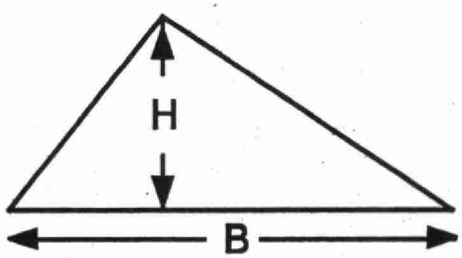
$$= 7 \text{ m} \times 4 \text{ m}$$

$$= 28 \text{ m}^2$$

TRIANGLES

A triangle is a 3-sided figure in which the sum of enclosed angles equals 180°. The area of a triangle is equal to one half the base length multiplied by the height.

Area =1/2 B x H
B = length of base
H = height of triangle



Example: Find the area of a triangle with a base length of 27 inches and a height of 3.4 feet.

Solution:

(1) Convert measurements to the same units

$$B = 27 \text{ inches} \times \frac{1 \text{ feet}}{12 \text{ inches}}$$

$$= 2.25 \text{ feet}$$

$$H = 3.4 \text{ feet}$$

(2) Enter values of length and width in formula

$$\text{Area} = 1/2\ B \times H$$

$$= 1/2\ (2.25 \text{ feet}) \times 3.4 \text{ feet}$$

$$= 3.825\ ft^2$$

$$= 3.8\ ft^2 \text{ (rounded off)}$$

CIRCLES

A circle is a figure enclosed by a curved line, every point on which is an equal distance from the centre. The curved line bounding the figure is called the circumference. The distance from the centre of the circle to any point of the circumference is called the radius. A line joining the circumference on either side of the circle and passing through the centre is called the diameter. The diameter is twice the length of the radius. The area of a circle is equal to the radius squared, multiplied by a constant.

$\text{Area} = \pi R^2$

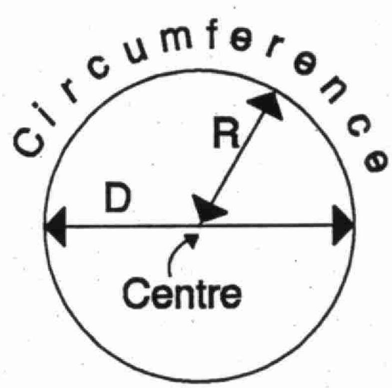
or

$\text{Area} = \pi D^2 / 4$

π = constant = 3.1416

R = radius

D = diameter



Example: Find the area of a circle with a radius of 3 metres.

Solution:

(1a) Enter value of radius in formula

$$\text{Area} = \pi R^2$$
$$= 3.1416 \times (3 \text{ m})^2$$
$$= 28.2744 \text{ m}^2$$
$$= 28.3 \text{ m}^2 \text{ (rounded off)}$$

The area may also be calculated using the diameter.

(1b) Enter the value of diameter in formula

$$\text{Area} = \pi D^2 / 4$$
$$= 3.1416 \times (6 \text{ m})^2 / 4$$
$$= 28.2744 \text{ m}^2 \text{ or } 28.3 \text{ m}^2$$

SURFACE AREA

Surface area is the total of the areas of all the surfaces of a figure. The formulas used above for area calculations are also used to calculate surface areas. First the figure must be broken down into its component parts, then the total area of these parts must be calculated.

CYLINDERS

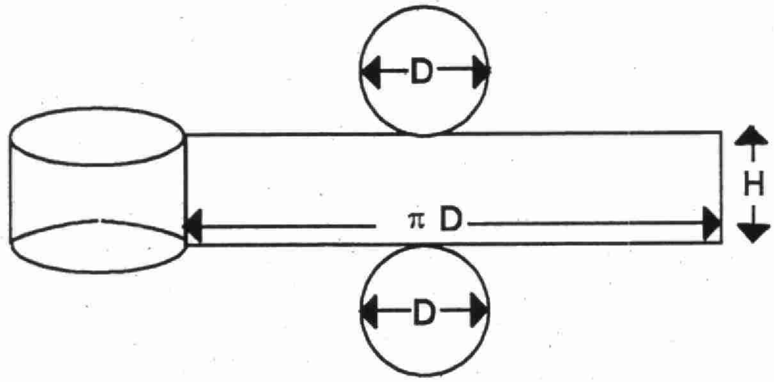
The surface area of a cylinder is composed of 3 parts: the top surface (a circle), the bottom surface (a circle), and the curved side surface (a rectangle). The **areas of the top and bottom surfaces** are the same, and can be calculated using the formula for the area of a circle.

$$\text{Area} = \pi D^2 /4 \qquad \text{or} \qquad \text{Area} = \pi R^2$$

The **area of the side surface** can be determined by imagining that the side surface is unrolled into a rectangle as illustrated below. The length of the rectangle is equal to the circumference of the top or bottom circle, and the width is the height of the cylinder.

$$\text{Area} = \pi D H \qquad \text{or} \qquad \text{Area} = 2 \pi R H$$

The surface area of a cylinder is the total of these 3 areas.



Example: Find the total surface area of a cylindrical tank with a base diameter of 18 metres and a height of 4 metres.

(1) Find the area of the top surface

Area $= \pi D^2 / 4$

$= (3.1416) \times (18 \text{ m})^2 / 4$

$= 254.5 \text{ m}^2$

(2) Find the area of the bottom surface

Area $= \pi D^2 / 4$

$= 254.5 \text{ m}^2$

(3) Find the area of the side surface

Area $= \pi D \times H$

$= 3.1416 \times 18 \text{ m} \times 4 \text{ m}$

$= 226.2 \text{ m}^2$

(4) Find the total surface area

Surface area $= 254.5 \text{ m}^2 + 254.5 \text{ m}^2 + 226.2 \text{ m}^2$

$= 735 \text{ m}^2$

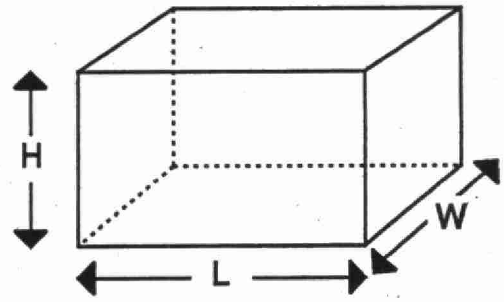
VOLUME

The volume of a three dimensional figure is the amount of space the figure occupies. Volume is measured in cubic units. Some metric units for measuring volume are: m^3, cm^3, and L. Some Imperial units for volume are: in^3 and ft^3. The aid sheet gives formulas for calculating the volumes of several common shapes. Be careful to keep your units consistent!

RECTANGULAR SOLIDS

The volume of a rectangular solid is equal to the area of the base multiplied by the height.

Volume	= Area of base x H
Volume	= L x W x H



Example: Find the volume of a reservoir that has a surface area of 100 m^2 and a depth of 2.4 metres.

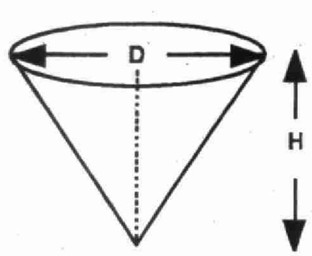
Volume = Area of base x H
= (100 m^2) x 2.4 m
= 240 m^3

CONES

The volumes of cylinders, prisms, and cones are also calculated by multiplying the area of the base by the height of the figure. Some of the formulas also need to be multiplied by a fraction, as shown on the aid sheet. For example, the formula for the volume of a cone is one third of the area of the base multiplied by the height.

Volume = 1/3 Area of base x H

Volume = 1/3 π R^2 x H or Volume = 1/3 (π D^2 / 4) x H
= 1/12 π D^2 x H



Example: Find the volume of a conical shaped hopper with a diameter of 2.1 metres and a height of 3.4 metres.

Volume $= 1/12\ \pi\ D^2 \times H$

$= 1/12\ (3.1416) \times (2.1\ m)^2 \times 3.4\ m$

$= 3.9\ m^3$

SPHERES

The volume of a sphere can be calculated using the following formula:

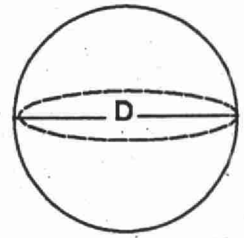
$$\text{Volume} = 4/3\ \pi\ R^3 \quad \text{or} \quad \text{Volume} = \pi\ D^3 / 6$$

Example: Find the volume of a ball with a radius of 0.33 m.

Volume $= 4/3\ \pi\ R^3$

$= 4/3\ (3.1416)\ (0.33)^3$

$= 0.15\ m^3$

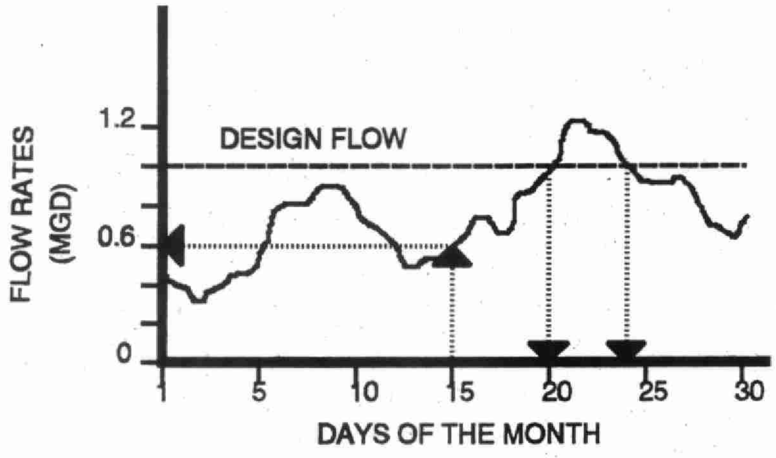


GRAPHS

Graphs and tables are convenient ways to present a large volume of data in a useable format. Operators should be able to create and interpret graphs and tables.

The framework of a graph consists of a grid of lines. Two of the lines, one horizontal line and one vertical line, are labelled with numbers giving the ranges of values shown on the graph. The horizontal line is called the x-axis and the vertical line is called the y-axis. In the case below, the x-axis shows the days of the month with values ranging from day 1 to day 30. The y-axis in this example shows the flow rates in million gallons per day (MGD) ranging from 0 to 1.2 MGD.

A line laid on top of this grid shows the relationship between the values of the x-axis variable and the y-axis variable. In this example, the irregular line shows the relationship between flow rate and days of the month. If we want to determine the flow rate on any day of the month, we can find this on the graph. For example, on the 15th day of the month the flow rate was about 0.6 MGD. You can find any other value in a similar way by following a grid line vertically to touch the irregular graph line, then following a grid line horizontally to see where it touches the y-axis (as shown below).



Example: The graph above, the rate of flow for each day of the month is shown. The design flow for this treatment plant is 1 MGD. On which days does the flow exceed the design flow?

First draw a line on the graph to show where the design flow occurs (dashed line). At the points where the irregular graph line crosses the dashed line showing the design flow, draw vertical lines to the x-axis and read the values. In this case the irregular graph line is above the dashed line between days 20 and 24. That means that the flow exceeded the design flow between the 20th and the 24th days of this month.

PUBLIC HEALTH/MICROBIOLOGY (ALL)

By definition **microorganisms** are those animals, plants and other living organisms which can not be seen or are barely visible by the naked eye. These include bacteria, algae (single celled photosynthesizing organisms), and viruses. The majority of microorganisms are harmless to humans, and may even aid human endeavours such as the digestion of food in the intestine, and the production of beer, cheese or yogurt. These bacteria are call **non-pathogenic**. Bacteria and other microorganisms which cause disease in humans are called **pathogens**.

Microorganisms share a number of different characteristics, apart from their small size. Generally, given the right conditions and enough food, microorganisms can reproduce extremely rapidly. This allows small bacteria populations to rapidly expand, potentially causing serious health problems. Many microorganisms can also form hard protective shells known as cysts. This characteristic allows the microorganisms to survive difficult periods such as low food, cold/hot temperatures or drought. This characteristic may also make microorganisms difficult to control.

Microorganisms are found in all surface water bodies. They originate from improperly treated sewage, stormwater runoff, septic beds, farm animal faeces, and natural sources. Water which has undergone the effective elimination or destruction of organisms capable of causing disease is said to be **disinfected**. Water may be disinfected through the use of chemicals such as chlorine, ultraviolet radiation or ozonation.

Aside from microorganisms, water treatment facilities may need to treat or monitor other potentially dangerous substances such as pesticides, organic chemicals, heavy metals, and ions such as cyanide. These chemicals may be natural or a result of human activities. As well drinking water treatment facilities are concerned with aesthetic characteristics (i.e. aspects of drinking water that are noticeable to the drinker) such as colour, taste, and odour.

Microorganisms also serve very important functions in the biological treatment of wastewater. In order to survive microorganisms require energy, carbon and other nutrients, which can be found in wastewater. Microorganisms which require dissolved oxygen to grow are known as **aerobic**. Those which can only grow in the absence of dissolved oxygen are called **anaerobic**. Both types can play an important role in a wastewater treatment facility, by breaking complex organic substances found in wastewater into simpler compounds, such as methane, carbon dioxide, nitrates, phosphates and water.

Most microorganisms can survive only in a limited range of conditions (oxygen level, temperature, pH, toxin levels, nutrients etc.). It is very important that an operator be aware of, and maintain these conditions in a biological treatment process.

ENVIRONMENTAL HEALTH (ALL)

Raw or improperly treated sewage can lead to the degradation of the environment. Sewage has a high nitrogen and phosphorus content. These are the same chemicals which are used to fertilize lawns or gardens. In natural streams and lakes excessive amounts of these chemicals will lead to increases in the population of algae and other microorganisms. These organisms will in turn deplete the amount of oxygen in the water, causing the death of fish and other important animals and plants. Long term release of sewage will reduce the diversity of life in a body of water. Temporarily diverting wastewater around treatment processes (known as a **bypass event**) may also cause large "fish kills" which greatly effect the long term health of the stream or lake. In addition to the fertilizer effect of sewage, heavy metals and other toxins will lead to severe environmental damage if treated inadequately. High discharge of suspended solids may also result in habitat destruction of streams, rivers and lakes.

WATER/WASTEWATER CHEMISTRY (ALL)

Chemistry may be defined as the science that deals with the composition, properties and changes undergone by matter under certain conditions. The treatment, distribution or collection of water and wastewater involves many chemical concepts and terminology. A basic understanding of chemistry is a pre-requisite to successful plant operation.

BASIC CONCEPTS

The term **matter** refers to anything which occupies space and has a mass. Matter may exist in solid, liquid or gaseous states. Depending on temperature and pressure, matter may undergo a **change of state**. For example as the temperature of ice raises above 0°C it will become a liquid, and as the temperature raises above 100°C the liquid will become a vapour.

The basic building block of all matter is known as an atom. There are many different types of atoms, each with their own mass and physical properties. Each type of atom is known as an element. Common examples of elements include hydrogen (the chemical symbol for which is (H), carbon (C), nitrogen (N), oxygen (O), phosphorus (P), and chlorine (Cl). If you wish to identify an element and many of its properties, a complete listing is provided in a *Table of Elements* (Appendix F).

If two or more different elements combine a compound is formed. When a compound is altered to form a new type of compound a **chemical change** has occurred. The burning of fuel is an example of a chemical change. As a result of this reaction, the elements of fuel are recombined with oxygen to create new compounds such as water and carbon dioxide. A chemical change is different from a change of state. A change of state does not result in compounds with different composition of elements.

Often chemical compounds are placed into categories based on their composition and characteristics. The presence of carbon is often used to divide chemicals into two groups. **Organic compounds** are those which are composed of carbon, hydrogen, oxygen and other elements. **Inorganic compounds** tend to be simpler and usually do not contain carbon.

When a compound undergoes a chemical change this is called a **chemical reaction**. Chemical reactions are often summarized in the form of equations. For example:

$$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$$

Chorine + Water ⇌ Hypochlorous Acid + Hydrochloric Acid

In the above chemical equation, two chlorine atoms (Cl_2) will react with one water atom to form one molecule each of hypochlorous and hydrochloric acids. Chemical reactions may proceed quickly or slowly depending on various conditions such as temperature, pressure and pH. Chemical reactions may also proceed in the reverse direction. In the above example under the right conditions hydrochloric and hypochlorous acids may form water and chlorine. The ⇋ symbol indicates that the reaction may proceed in either direction. Often chemical reactions will be written using the → symbol, indicating that under normal conditions the reaction will proceed in this direction.

Oxidation is a common chemical reaction in water/wastewater treatment. Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons (a component of an atom) from an element or compound. In treatment processes, oxidation results in the transformation of organic matter to more stable substances. Oxygen and chlorine are two strong compounds which aid in the oxidation of organic material.

ACIDS, BASES & SALTS

In the water/wastewater industry one group of reactions which are very important involve acids, bases and salts. Acids, bases and salts are commonly used for pH adjustment, flocculation, sedimentation, disinfection, corrosion control, water softening and taste, colour and odour control.

When an acid, base or salt is added to water, the compound will split into two separate parts. When this occurs the compound is said to have **disassociated**. An **acid** is a compound which will release **hydrogen ions** (H^+) when it disassociates. The stronger the acid the more hydrogen ions the compound will release. An example of an acid is hydrochloric acid;

$$HCl \rightleftharpoons Cl^- + H^+$$

Hydrochloric Acid ⇌ *Chloride ion* + *Hydrogen ion*

When a **base** is added to water and disassociates it will release **hydroxyl ions** (OH^-). The stronger the base the more hydroxyl ions will be released. This is illustrated in the equation below.

$$NaOH \rightleftharpoons Na^+ + OH^-$$

Sodium Hydroxide ⇌ *Sodium ion* + *Hydroxyl ion*

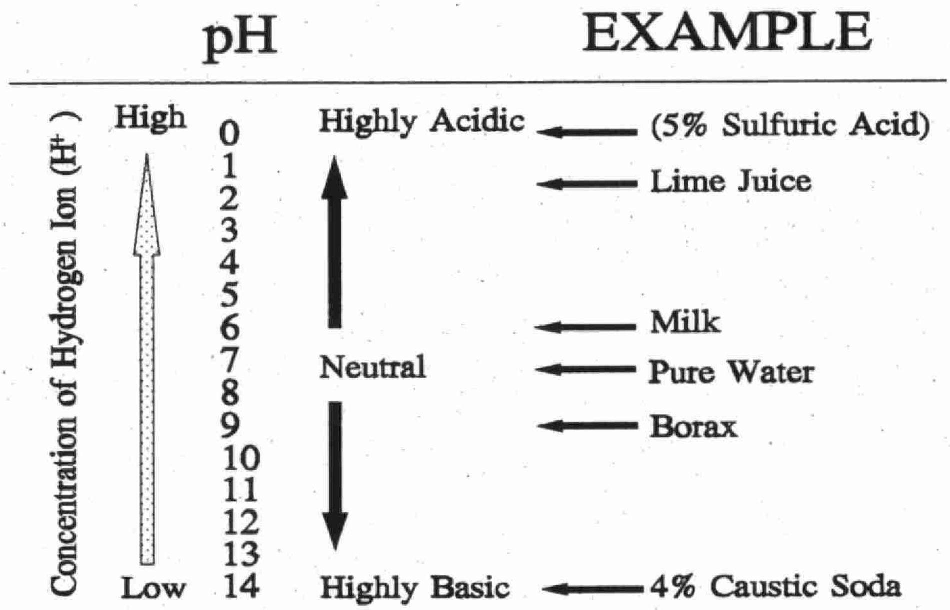
A **salt** will not release hydrogen or hydroxyl ions when it dissociates. A good example is common salt, sodium chloride;

$$NaCl \rightleftharpoons Na^+ + Cl^-$$

Sodium Chloride ⇌ *Sodium ion* *Chloride ion*

pH SCALE

The pH scale is a method used to measure the strength of an acidic or basic solution (basic solutions may also be referred to as alkaline solutions). The scale ranges from 0-14 with acids having a pH of less than 7, and bases a pH greater than 7. A solution which is neither acidic or basic is called a neutral solution and has a pH of 7. Each increase in 1 in the pH scale, indicates a solution which is 10 times more basic. For example a liquid with a pH of 8 is ten times more basic than a liquid with a pH of 7.



When acid and base solutions are combined a salt will form and the hydrogen (H^+) and the hydroxyl (OH^-) ions will combine to form water (H_2O). If the acid and base solutions are approximately the same strength (i.e. the same amount of hydrogen and hydroxyl ion concentrations) the solutions will neutralize. This is an important reaction in the water/wastewater treatment industry.

Acidity and alkalinity are terms used to describe a water's ability to buffer a base or an acid respectively. Acidity and alkalinity are measured in milligrams per litre equivalent amounts of calcium carbonate.

SOLUTIONS

A solution is made up of two or more different parts. One component is known as the **solvent** which will dissolve the other component(s) which are called the **solute(s)**. For example when sugar is dissolved in water, the sugar is the solute and the water is the solvent. The concentration of a solution refers to the amount of solute which is dissolved in the solvent. The greater the amount of solute the higher the concentration. There are several methods for measuring the concentration of a solution. These include molarity (M), normality (N), and calculating the mass of a solute as a percent of the total mass of the solution.

$$\frac{mass\ of\ solute}{mass\ of\ solution} x\ 100 = \%concentration$$

$$\frac{30\ g\ sugar}{120\ g\ solution} x\ 100 = 25\%\ concentration$$

In water/wastewater treatment it is often desirable to remove a solute from solution. Often chemicals will be added to the solution which causes a chemical change in the solute into an insoluble compound. This reaction is known as **precipitation** and the compound which settles out of the solution a **precipitate**.

COMMON CHEMICALS AND PARAMETERS

The following list includes many of the chemicals or chemical concepts which you will come across as an operator of a treatment, distribution or collection system. Additional terms are defined in the glossary (Appendix H). In water chemistry, the most common unit of measurement is milligrams dissolved, or suspended particles in a litre of water. The expression used is mg/L. Occasionally mg/L will be expressed as Parts Per Million (PPM), although the two are not strictly equivalent.

Activated Carbon

Activated carbon is a very porous material which is used to adsorb particles from water. **Adsorption** is a process where particles are trapped on the surface of a material. This differs from **absorption**, which refers to the trapping a particles *within* the body of another material. Because of its high surface area, activated carbon is able to remove soluble and colloidal materials which sand filters cannot. It can be cleaned by intense heat and reused.

Alum (Aluminum Sulphate)

This metallic salt is often used in the water treatment as a **chemical coagulant**. Coagulants will react with the water and cause the destabilization of suspended particles. This destabilization results in the particles sticking together to form a **floc**. With gentle mixing of the water the flocs will gather together and be easily removed through filtration or sedimentation. Although alum is the most common coagulant, many other chemicals are used.

<u>**Chlorine**</u> (Cl)

Chlorine is the most common method of disinfection used in Ontario. Chlorine is available as a solution in water (**sodium hypochlorite**), powder (**calcium hypochlorite**) or gas. The liquid is similar to a strong "Javex" solution and is relatively safe to handle. Chlorine gas, on the other hand, is extremely dangerous to handle, a severe respiratory irritant which may result in death, and is flammable and explosive.

Chlorine gas is a greenish/yellow colour. It has a penetrating odour. It is heavier than air and thus will concentrate in low lying enclosed areas.

Chlorine gas is supplied in pressurized metal cylinders. These cylinders must be handled with special care. Because of the pressure within the cylinders, chlorine is in liquid form. As the chlorine is depressurized into a gas its volume increases 450 times. Before working with chlorine gas, operators must ensure that they are aware of the mechanical procedures, safety procedures and how to use emergency leak stoppage equipment.

Leaks of chlorine gas can be detected by using commercial ammonia, which when passed below the leak produces a white smoke. To work on a chlorine gas leak an operator must wear a self contained breathing apparatus.

Chlorine, in both solution and gas forms, is an effective low cost method of disinfection. When using chlorine, it is important to ask how much chlorine is required and how long the chlorine should be in contact with the water. The amount of chlorine used is called the **dosage**. The time required for disinfection to occur is called the **contact time**. When chlorine is first introduced to water it will combine with organic and inorganic compounds. The chlorine which is required to combine with these compounds is called the **chlorine demand**. Some of the chlorine will react with ammonia to create what is often called **combined chlorine**. This form of chlorine has good disinfecting properties. Chlorine which does not combine with other compounds is known as **free chlorine**. The sum of the combined chlorine compounds and free chlorine is known as the **chlorine residual**.

$$\textit{chlorine dosage (mg/L)} = \textit{chlorine demand (mg/L)} + \textit{chlorine residual (mg/L)}$$

$$\textit{chlorine residual (mg/L)} = \textit{combined chlorine (mg/L)} + \textit{free chlorine (mg/L)}$$

Free chlorine is a more effective disinfectant than combined chlorine but is not as stable or as long lasting. An advantage of chlorine over other disinfection techniques is its ability to disinfect long after it was applied. This is important for ensuring that water remains safe in a distribution system or water storage tank.

Alternative methods of disinfection are becoming ever more common as a result of concerns regarding the long term effects of chlorine compounds (trihalomethanes) on humans and the environment. Trihalomethanes are produced when chlorine reacts organic material. These alternatives include ozone, ultra violet light as well as alternative chemicals such as chlorine dioxide.

Colour

Many surface waters, particularly those originating from waters with decaying or organic debris, will have colour which is unacceptable to domestic customers and to some industrial processes. Colour is one of the more difficult problems to handle in the treatment of water. Colour compounds may also be precursors to trihalomethane formation.

Hardness

Hard waters are those that, as a result of high dissolved mineral salts, require considerable amount of soap to produce a foam or lather. Hard water will also leave a scale in hot water heaters and boilers. **Hardness** is primarily caused by the presence of dissolved calcium and magnesium salts. Hardness is normally found in waters running through or over limestone. Hardness is expressed in milligrams per litre as calcium carbonate (mg/L as $CaCO_3$). Hardness can be removed using chemicals in treatment plants or using ion exchange water softeners in the home.

Nitrogen (N)

Nitrogen is a vital element for the life processes of living organisms. Any discussion of nitrogen in this regard is very complex because of the very large numbers of compounds, both organic and inorganic, associated with nitrogen. Nitrogen is an important consideration for wastewater effluent since it acts as a nutrient which stimulates plant growth. In terms of drinking water, nitrites are known to be toxic, particularly to infants. In addition the presence of nitrogen compounds is often an indication of pollution.

Oxygen (O)

The amount of free oxygen in water is known a dissolved oxygen. The total amount of oxygen which can be dissolved in water is dependant upon temperature. The level of oxygen in water will determine what types of organisms can survive. The release of untreated or partially treated sewage may lower a stream's dissolved oxygen level, thereby making it uninhabitable to many species of plants, fish and other animals. In the absence of oxygen a body of water is said to be **septic**. From a treatment perspective certain types of wastewater treatment processes can only occur in the presence or absence of oxygen. Thus maintaining the correct dissolved oxygen content is very important in many processes within a wastewater treatment plant.

The effect wastewater has upon a stream is often estimated based upon the **Biochemical Oxygen Demand (BOD)** of the wastewater. BOD is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The BOD test is used to determine the organic strength (i.e amount of organic pollution) of wastewater. The higher the BOD (expressed as mg/L) the greater the amount of organic material.

Phosphorus (P)

Phosphorus and phosphorus compounds are important in both water treatment and wastewater treatment. In industrial water treatment, phosphates are applied to water to control scaling in boilers. Phosphorus is also a requirement for plant and bacterial growth. Therefore, some phosphorus is necessary in biological wastewater treatment processes (i.e. activated sludge) to ensure that there is sufficient nutrients for the microorganisms to remain viable. On the other hand, excessive phosphorus discharged into a receiving stream promotes plant growth leading to high levels of algae and other plant materials in the water. Wastewater treatment plants which discharge to the Lower Great Lakes area are required to remove excess phosphorus from their effluents.

Solids

The determination of solids concentrations in water is quick and simple. These measurements thus provide a very quick indication of water quality. There are numerous types of solids that are analyzed, including:

Dissolved solids	- solids which are able to pass through an extremely fine mesh filter.
Settleable solids	- those solids which, when left for a given period of time, will settle out.
Suspended solids	- solids which either float or are suspended in water, and are measured by entrapment in/on a filter.
Total solids	- includes dissolved, settleable and suspended solids. Measured by weighing the residue left when a given volume of water is evaporated.
Volatile solids	- solids which, when a total solid sample or suspended solid sample is heated to a high temperature, are burnt off. These solids approximate the amount of organic material in the water.

Turbidity

The term **turbidity** is applied to waters containing suspended matter which interferes with the passage of light. It can be caused by a wide variety of suspended materials ranging in size from colloidal to coarse particles. **Colloids** are very small particles suspended in water which cannot be removed through sedimentation or filtration without the use of chemicals. Turbidity can result from erosion or disturbance of river bottoms, and material originating from domestic and industrial wastewaters. Turbidity itself may not be dangerous to human health but may provide an indication of pathogenic or other harmful material.

From a public perspective turbidity has two main effects. The first is aesthetic; a customer of drinking water expects to receive water with no noticeable cloudiness. Secondly, turbidity allows harmful microorganisms to become enveloped within solids and therefore protect themselves from disinfection. Turbidity removal normally requires both physical and chemical processes.

SAMPLING OF WATER/WASTEWATER

One of the most common activities in any water treatment, wastewater treatment, water distribution and wastewater collection facility, is obtaining samples of the water. Provincial laws and the facility's Certificate of Approval set specific sampling requirements to ensure that the final product of the treatment facility meets the required health and environmental standards. In addition sampling within a facility is an important tool for optimizing the operation of the treatment processes.

Whatever the purpose of the sampling, it is essential to sample in a consistent, accurate manner. All steps must be taken to eliminate any chance of contaminating the sample or the containers used in sampling. Sampling should be performed using a set routine to maintain consistency between sampling periods. Sample locations should also be consistent and must be chosen in order to obtain a water/wastewater sample which is *representative* of the actual flow of water/wastewater. It is important to remember that depending on how the sample is going to be analyzed, different sampling procedures may be required. Finally it is essential to label all samples, making any notes which may impact the interpretation of the test results.

Typically two types of sampling occur in water/wastewater facilities: **grab sample** and **composite sample**. A grab sample is a single sample taken at one place and time. These samples may be appropriate where the water quality and quantity are not variable. A composite sample is a series of samples taken over a period of time which are combined to form a single sample. This type of sampling is necessary if the water quality changes greatly over time. Composite samples are often collected using automatic samplers.

MINISTRY OF ENVIRONMENT AND ENERGY OBJECTIVES

The Ministry of Environment and Energy sets objectives for the quality of the ambient water and for treated drinking water. The objectives are based on the latest medical and environmental evidence. The Ministry refers to these objectives when establishing specific criteria for the drinking water quality or effluent quality which must be met at each facility. These plant specific criteria are stated in the Certificate of Approval which the Ministry issues to each facility. As an operator it is important to realize that your facility has legal requirements for maintaining certain chemical and physical parameters within established limits.

BASIC ELECTRICITY (ALL)

Municipal facilities contain a variety of electrical equipment. It is important for operators to understand the basic electrical vocabulary used to describe this equipment.

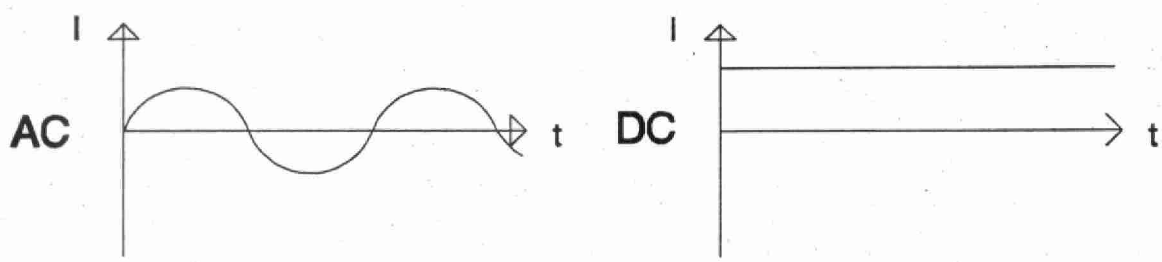
VOLTAGE

Voltage (V) is the electrical potential or potential difference between two points. It indicates the strength of the "push" or "pressure" on current in an electrical circuit. Voltage is measured in volts (V).

CURRENT

Current (I) is a flow of electric charge. It can be compared to the current, or rate of flow of water, in a river. Current is measured in amperes (A).

Current may either be alternating or direct. Alternating current (AC) changes strength and direction in a wave pattern with respect to time (t). The typical rate of change (or frequency) of alternating current is 60 cycles per second (Hz). Direct current (DC) remains at a constant strength and direction.



Wires, fuses and circuit breakers are rated as to the maximum current which they may carry. When carrying more than their rated capacity wires or appliances may overheat and cause fires. Fuses and circuit breakers are designed to burn out or to break a circuit in preference to the burning of wire conductors.

RESISTANCE

Resistance (R) is the opposition offered by the wires of a circuit to the passage of electric current. This is similar to friction loss in pipes. Resistance is measured in ohms (Ω).

Voltage, current and resistance are related using the formula:

Voltage (V) = Current (I) x Resistance (R)
$V = I R$

POWER

Power (P) is the rate at which work is done, or energy is produced. It can be compared to the horsepower of a car's engine. Power is measured in Watts (W).

Power is related to voltage and current using the formula:

Power (P) = Voltage (V) x Current (I)
$P = V I$

BASIC HYDRAULICS (ALL)

Hydraulics is the study of water or liquid at rest or in motion. Some common terms used when discussing hydraulics are defined below, along with their standard units of measurement.

VELOCITY

Velocity is the average speed at which water moves through a certain cross section or past a certain point. This is usually measured in kilometres per hour (km/h) and metres per second (m/s) in the metric system and miles per hour (mph) and feet per second (fps) in the Imperial system.

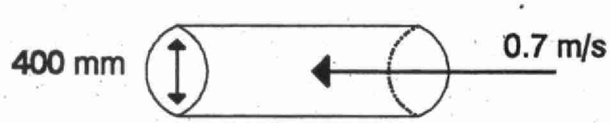
FLOW RATE

The **flow rate** is the measurement of water or liquid that flows through a conduit or pipe during a certain time period. This is usually measured in litres per second (L/s), cubic metres per second (m^3/s) and megalitres per day (ML/d) in the metric system or gallons per day (gpd) in the Imperial system.

Rate of flow may be calculated by multiplying the velocity of the fluid by the cross-sectional area at right angles to the direction of flow. Formulas for rate of flow are given on the aid sheet found in Appendix E.

Flow Rate = A x V
A = Area
V = Velocity

Example 1: Calculate the flow rate in a 400 mm diameter pipe if the velocity is 0.7 m/s.



(1) Calculate cross-sectional area of pipe.

Area $= \pi D^2 / 4$

$= 3.1416 \text{ x } (0.4 \text{ m})^2 / 4$

$= 0.126 \text{ m}^2$

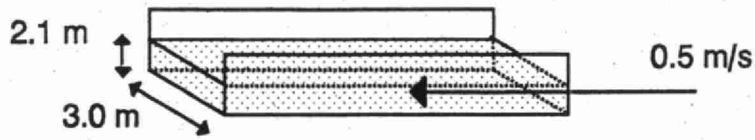
(2) Calculate the flow rate

Flow Rate $= \text{A x V}$

$= 0.126 \text{ m}^2 \text{ x } 0.7 \text{ m/s}$

$= 0.088 \text{ m}^3\text{/s}$

Example 2: Calculate the flow rate (m^3/s) through a rectangular channel with a width of 3 metres and a depth of 2.1 metres. The water has a velocity of 0.5 m/s.



Flow Rate = W x D x V

= 3 m x 2.1 m x 0.5 m/s

= 3.15 m^3/s

MEASURING FLOW RATE

Flow rate is one of the most important measurements which an operator uses. This measurement will provide information on the detention times in tanks, flow between various processes or sections of a distribution/collection system, chemical feed rates, amount of water treated/pumped, costs of treatment, and the need for system expansion. There are numerous methods for measuring flow rate. The types of measurement are dependent on whether the water is flowing in a closed pipe or in an open channel. Open channels are measured using **weirs or flumes**. A weir is a dam or obstruction in the channel. A flume is a specially shaped constriction in the channel. In both cases the flow rate is related to the height of water at a particular point. Some of the common methods of measuring closed pipes include venturi meters, ultrasonic meters, magnetic meters, Doppler meters and orifice meters. Although flow meters are vital in the operation of a system, their usefulness depends on proper operation, calibration and maintenance.

PRESSURE AND HEAD

When water flows through a system under force, that force measured per unit of area is termed pressure. Pressure is usually measured in kilopascals (kPa) in the metric system and pounds per square inch (psi) in the Imperial system. Static pressure refers to the force exerted when water is at rest and not flowing. Pressure exerted by flowing water is known as dynamic pressure.

It is often more convenient to express pressure in terms of a height of a column of fluid of constant unit weight. Therefore, the pressure at the bottom of a water column depends directly, and only, on the height of the column. When pressure is expressed in this way it is commonly referred to as **pressure head**. The head may be expressed in terms of feet of water column or inches of mercury in the Imperial system, or metres in the metric system.

Pressure can be measured using pressure gauges (a Bourdon pressure gauge is the most common) or with the use of manometers.

FRICTION LOSS IN PIPES

Friction occurs whenever there is flow through pipes. Friction causes a loss of head. Friction losses depend on the velocity or rate of flow, the length and size or diameter of a pipe and the apparent roughness of the pipe surface contacting the water. For a particular pipe, the larger the pipe diameter or the smoother the interior pipe surface, the lower the head loss due to friction. For this reason, pipe size will influence the velocity at which the water can flow through the system. If all else is equal (i.e. smoothness, pipe material and head) the smaller the pipe diameter the higher the velocity. As velocity increases friction losses increase, reducing the pressure at the outlet. This friction loss must be made up by way of higher energy inputs (for example additional pumping).

WATER HAMMER

When operating a distribution system it is important to understand the effects of pipe size and **water hammer**. As velocity increases friction losses increase, reducing the pressure at the outlet. This friction loss must be made up by way of higher energy inputs.

Water hammer occurs when a moving fluid is suddenly stopped. The energy which must be absorbed within the system can create pressures which will destroy the piping and appurtenances. One can think of water hammer like a speeding train which is forced to stop very suddenly. Although the locomotive stops in its tracks the cars which follow derail since their energy cannot be absorbed by the train. To avoid water hammer, valves must be operated very slowly. Operators must be aware of situations where water hammer can have costly or disastrous effects.

CAVITATION

When operating pumps it is important to follow the pump directions. Cavitation can occur as a result of very low pressure within a pump. This low pressure causes the water to boil, releasing tiny bubbles. The bubbles will then collapse, with enough force to damage the pump impeller. Cavitation can be avoided if the pump capacity, speed, head and suction lift are properly determined. Cavitation can cause rapid damage to the impeller of a pump. A noise, similar to hammering of the pump impeller, will indicate to the operator that cavitation is occurring.

WATER TREATMENT (WT)

Water in the natural environment contains many contaminants which make it unsuitable for human consumption. These contaminants include pathogenic microorganisms, colour, odour, suspended matter and chemicals which either endanger public health, are unappealing to the senses, or cause engineering problems. Treatment processes remove or decrease the contaminant levels so as to make the water fit for human consumption. The process described below is a typical process used in Ontario when water is drawn from a relatively clean body of surface water. Figure 1 illustrates the flow of water through a treatment facility. Groundwater supplied systems may have simpler treatment facilities due to the quality of the source water.

Raw water is pumped from the source. The types of treatment processes which follow will depend on the overall water quality of the raw water. Often water (especially surface water) will initially pass through screens to ensure that large debris does not damage pumps and other equipment. The water may be dosed with chlorine or other chemicals to remove potential odours, to kill algae, or to control zebra mussels. This stage of chlorine dosing is sometimes referred to as **pre-chlorination**. (See the Water/Wastewater Chemistry section for more details).

Raw water will contain small particles, known as colloids. These colloids produce a cloudy appearance known as turbidity. Turbidity can shield microorganisms from disinfection. Colloidal particles either do not settle or are very slow to settle. For this reason chemicals are added which will react with the colloids and the water to form relatively large, easily settleable particles. The mixing of these chemicals (**coagulants**) with the water is known as **coagulation**. The reaction between the coagulant and the particles is very fast and thus the chemicals must be mixed quickly and thoroughly in the water to assure that it has achieved maximum effect. For this reason the process is called **rapid** or **flash mixing**. The most commonly added chemical for this purpose is aluminum sulphate (**Alum**). Ferrous sulphate, ferric sulphate and various polymers are also commonly used coagulants. The water then passes into a flocculation tank. In the **flocculation** process the water is mixed slowly and the particles (floc) build in size and density. The purpose of flocculation is to achieve optimum size particles which will readily settle out of the water.

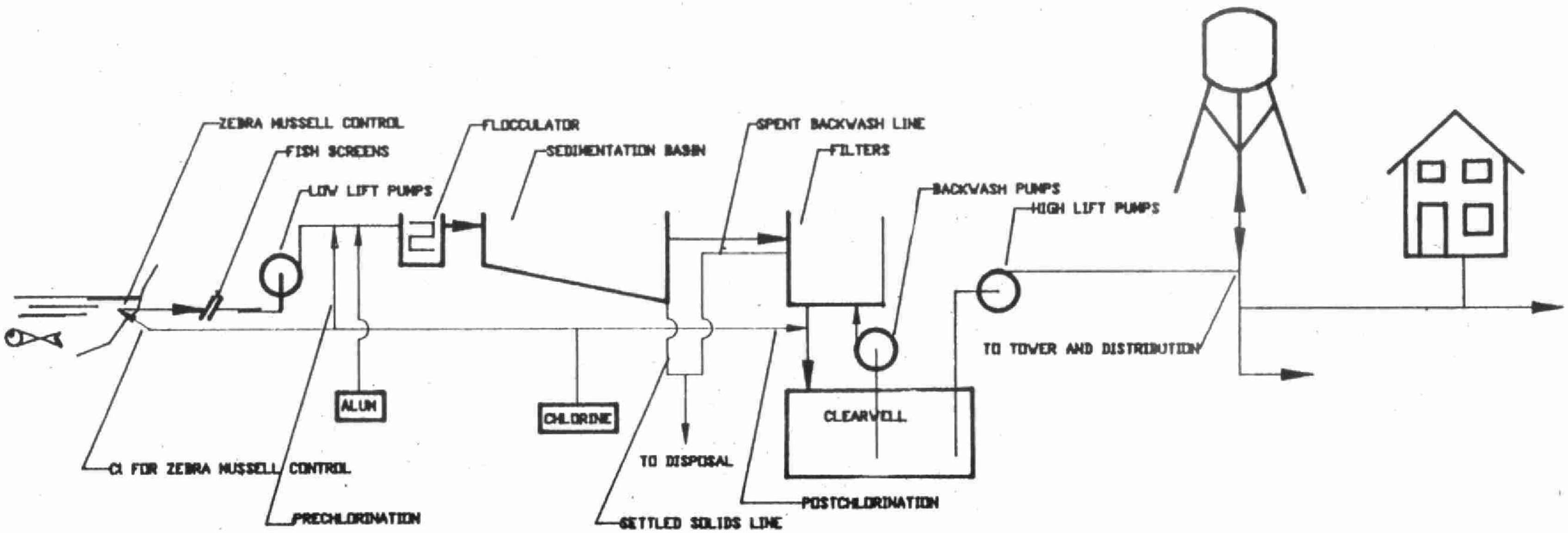


FIGURE 1: SIMPLIFIED SCHEMATIC OF A TYPICAL WATER TREATMENT FACILITY

The addition of too much or too little coagulant decreases the efficiency of the treatment process. For this reason it is very important to determine the correct dosage. The optimal chemical dose is determined in the laboratory using a "**jar test**" which simulates the conditions in the plant on a small scale.

From this point the water normally flows into **sedimentation tanks** (or **clarifiers**) wherein the heavier matter settles due to gravity. The time the water remains in these tanks is known as **detention time**. The settled material is usually disposed of in the sanitary sewers. Surface waters may also require a pre-sedimentation period, before any other treatment process in order to remove very large material, such as sand and organic debris.

The next step in the process is **filtration**. Removing as much suspended particles as possible is very important for the operation of a treatment facility. Not only will the water appear clean to the consumer, but removing suspended particles eliminates the possibility of dangerous bacteria being protected from the disinfection process. The most common type of filtration process is known as the rapid sand filtration. Although there are various types of rapid sand filters, most operate using the same general principles. These filters normally contain layers of anthracite, sand, and/or gravel. The tiny pore spaces in the filter "media" trap the suspended particles. Most matter which has not settled in the flocculation tank is entrapped by the filter media. Activated carbon may also be used to remove taste and odour problems. The quality of the water, as it leaves the filtration process can be determined by its turbidity. High turbidity may indicate that the filters require cleaning.

Filters are cleaned on a regular basis (usually between 1 - 4 days depending on the facility) by a process known as **backwashing**. During this process the normal water flow is shut off and fully treated water is pumped up, backwards, through the filter media to remove the entrapped matter. The backwash water will be further treated to remove the solids or routed to the sanitary sewer.

Before the water is distributed to the community one or more chemicals may be added to help disinfect, adjust pH, or remove other impurities. The most common addition is chlorine, used, primarily, to kill harmful microorganisms in the water. Chlorine, when used as a disinfectant, is added after solids removal but at a point which will allow complete mixing. It is necessary to ensure that the chlorine has sufficient time to react with the water and the microorganisms (this period of time is known as the chlorine contact time). For this reason the water and chlorine will be allowed to react in a **chlorine contact chamber** or **clearwell**. In this chamber the chlorine residuals are raised to the required standards. (Additional information on chlorination can be found in the Water/Wastewater Chemistry section above). Other disinfection methods such as ozonation and ultraviolet radiation (UV), are also used.

Taste and odour in drinking water is a common consumer complaint. By themselves taste and odour do not cause any health problems. To encourage consumer usage it is important for treatment facilities to minimize their impact. Several methods are in common use to combat taste and odour including **aeration** (i.e. mixing air in water), addition of chemicals such as chlorine or potassium permanganate, and the use of activated carbon. Generally, water of high oxygen content and low temperature produce a superior tasting water.

Other compounds such as iron and manganese may also be treated if their concentration is too high. The most common methods of treatment are aeration, chlorination, addition of chemicals or ion exchange. Many treatment systems will also add fluorine to the water to prevent tooth decay. Chemicals may also be added to adjust the pH of the water. pH adjustment is often necessary to optimize the coagulation process. Waters which are corrosive in nature may also be treated chemically before distribution.

After the water is treated it flows to a large tank, normally called a clearwell or chlorine contact chamber, where it is pumped to the distribution system.

WATER DISTRIBUTION (WD & WT)

Operators of water distribution systems must ensure that their clients have access to clean, safe water, while maintaining a sufficient pressure and volume to meet all of the users demands. Duties of a distribution system operator typically include operation of pump stations, location and repair of water main breaks, cleaning of distribution lines, chlorination of water distribution lines, reservoirs or storage containers and thawing of distribution lines during winter. Operators should always be aware of the consequences of cross-connections between a water distribution system and an unapproved source of water. Cross connections have lead to serious public health problems in many cities.

Water distribution systems are designed to meet peak flows and fire fighting needs while maintaining uniform pumping and treatment rate. The systems consist of piping, pump stations, and storage facilities such as reservoirs, elevated tanks and standpipes. In addition, there are numerous appurtenances such as valves, fire hydrants, meters and service connections. It is essential that distribution systems are operated to minimize supply interruptions, protect the water from contamination and maintain a positive pressure in the system at all times. Pressure within the system is provided by elevated storage reservoirs and/or pumps (in most systems the pressure is maintained between 240-550 kPa). It is extremely important to maintain a positive pressure within all portions of the system, not only to serve firefighting and customer needs, but also to prevent contamination of the system. Lack of positive pressure can cause contaminated ground water to enter pipes through cracks. As well, negative pressure may draw contaminated water from an unapproved source of water.

Water distribution systems must also be prepared to operate under unusual conditions. These can include excessive demands caused by firefighting, or broken or frozen water mains. In addition pump failures can create serious problems. Plans need to be prepared and taught to all staff *before* an emergency occurs.

Storage tanks and **reservoirs** are used to provide the community with emergency storage capabilities. It also allows the treatment facility to produce excess water during slow periods for use during periods of high demand. In this way the water treatment facility can be designed for the average demand rather than the peak demand.

In most distribution systems the topography of the land requires the use of **pumping stations** to lift the water to a higher elevation and to maintain a positive pressure within all sections of the system. Several type of pumping stations are in common use. Stations may elect to use a pump large enough to handle the maximum flow rate although this tends to be inefficient. Stations may also use a variable speed motor to decrease the pumps capacity during low flow periods. Alternatively the station may consist of two or more pumps of different sizes to match the required rate of flow. Usually backup pumps will be available in the case of failure.

The main distribution pipes within a system are known as the **trunk mains**. Smaller diameter pipes branch off and distribute water to individual streets and houses. Commonly used piping materials include, polyvinyl chloride plastic (PVC), asbestos cement (AC), ductile iron (DI), and concrete pressure pipe (CCP).

Valves are used within a distribution system to isolate portions of the system for repair, cleaning, maintenance or adding additional lines. Valves may also be used to regulate the flow or pressure of water within a pipe. Different type of valves may be used for different applications.

Hydrants are used to fight fires and to flush lines and may be used to obtain water for construction purposes. It is important to be properly trained to operate hydrants. Improper use may result in damage, which could jeopardize the community's firefighting abilities.

Some chlorine should remain in the water distribution system in order to continue disinfecting the water. Problems of taste and odour can occur because of an excessive chlorine residual or no residual. In drinking water, a residual of about 0.2 mg/L is optimal. Operators must be particularly careful to always have a chlorine residual in reservoirs and on dead ends. The chlorine residual should be tested regularly. The Ministry of Environment and Energy provides guidelines regarding appropriate sampling frequencies. Taste and odour complaints in part of the distribution system may indicate low levels of chlorine residuals in portions of the distribution systems. In these cases it is often necessary to **rechlorinate** the water at various locations throughout the distribution system to ensure the optimal residual level is maintained. Failure to maintain sufficient chlorine residual in the distribution system has lead to the out break of disease in some North American communities.

The chlorine residual may be in the form of free chlorine or combined chlorine. Combined chlorine has a considerably lower disinfecting power than free chlorine. On the other hand, free chlorine does not last as long. The choice of which type of residual should be at least partly based on the bacteriological and chemical quality of the water and the type of treatment used.

Periodically, the mains should be **flushed** to remove deposits from the pipelines. Flushing is normally achieved by opening a hydrant. Failure to flush the distribution pipes may lead to taste, odour, turbidity and disease problems. Leaks in the distribution system are also a concern for operators. Not only do leaks increase the amount of water which must be treated but can also result in contamination of the drinking water during backflow events. **Backflow** may occur under certain circumstances when the water pressure is turned off, resulting in a negative pressure in the pipe. This negative pressure results in the flow of water in the reverse direction. Backflow preventers are commonly used to prevent contamination of the lines.

All of the components of a distribution system operate together as one. An operator must be aware of the system hydraulics, operating limitations, water quality, maintenance requirements and response times in order to meet the demands of the community.

WASTEWATER TREATMENT (WWT)

Sewage contains many contaminants which must be removed or reduced before it can be returned to the natural environment. These contaminants include solids, BOD (a term to describe the amount of oxygen required by microorganisms to stabilize the matter), nutrients such as nitrogen (N) and phosphorous (P) which promote algae growth, pathogenic microorganisms and harmful chemicals. The process described below is typical of those found in wastewater treatment facilities in Ontario and is illustrated in Figure 2. The treatment processes are commonly divided into four steps: **preliminary, primary, secondary** and **tertiary treatment.**

PRELIMINARY TREATMENT

Sewage entering a wastewater treatment plant (WWTP) initially passes through a series of devices designed to remove or reduce in size large solids, grease, scum and grit before it enters further treatment processes. Coarse screens (also known as **bar screens**) are used to remove large objects from the wastewater. Larger particles may also be removed from the wastewater by chopping or shredding, in a process commonly known as **comminution**. After the screens and shredders, grit, such as sand, eggshells, stones and gravel, is removed in **grit channels** or chambers. These initial, preliminary treatment steps are necessary to ensure that large objects or grit do not damage piping or equipment in the treatment facility. Preliminary treatment precedes all municipal wastewater treatment facilities, no matter what other treatment processes are used.

PRIMARY TREATMENT

In some facilities, the sewage then flows to **primary settling basins** (often called the **primary clarifier**). In this process flow velocity is slowed so that solids settle or float to the surface. The settled and floated material is then removed and pumped to sludge handling facilities, while the decanted liquid proceeds to secondary treatment. This process is a physical process since it relies on gravity to separate settleable materials from the liquid. Primary treatment will remove 30 - 40% of the BOD and 40 - 60% of the suspended solids from the sewage.

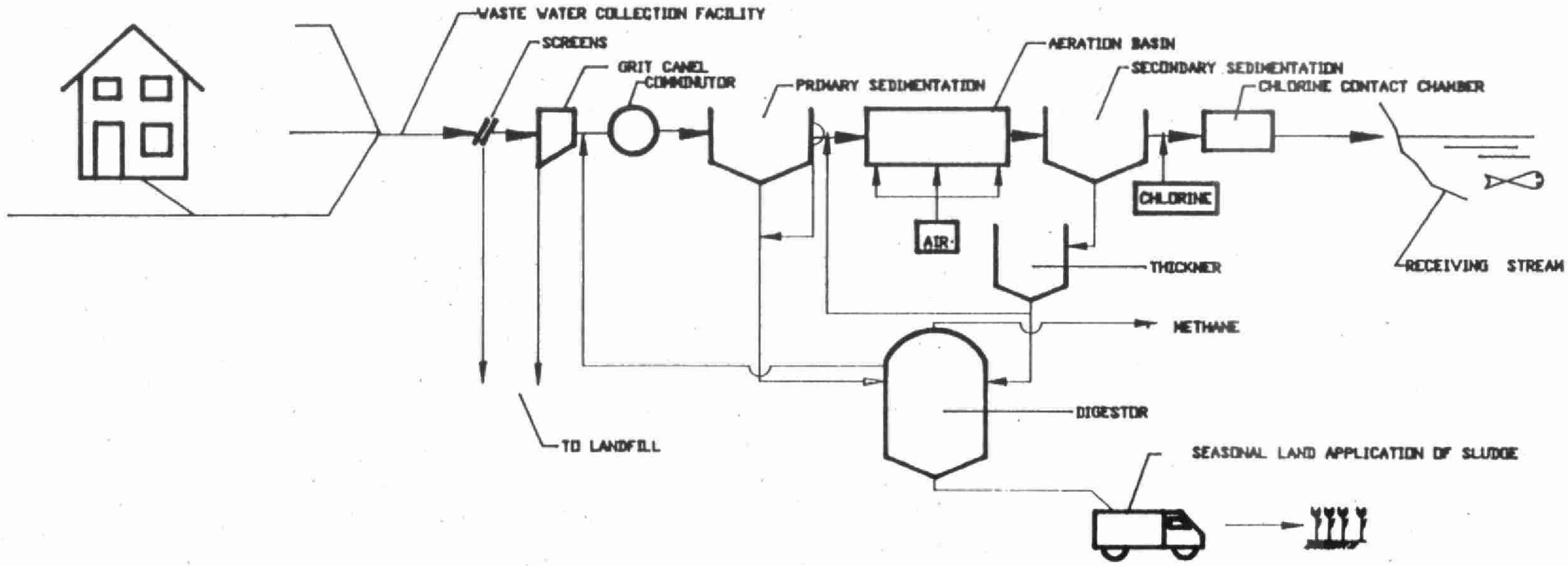


FIGURE 2: SIMPLIFIED SCHEMATIC OF A TYPICAL WASTEWATER TREATMENT FACILITY

SECONDARY TREATMENT

Although the primary treatment has removed large settleable and floatable materials, the wastewater still contains a large amount of dissolved or unsettleable impurities. In most treatment facilities in Ontario a greater degree of treatment is desired. To achieve this higher quality the effluent from primary treatment (or occasionally directly from the preliminary treatment) is routed to **aeration tanks** where it is mixed with a bacterial mass, known as **activated sludge**. The bacteria mass (also known as the biomass) consumes the BOD as "food". Because these aerobic microorganisms require dissolved oxygen to survive air must be added in the aeration tanks. This is achieved with the use of surface aerators or air diffusers. The dissolved oxygen level must be monitored carefully since the microorganisms are sensitive to drops in the dissolved oxygen.

As the microorganisms multiply they will tend to clump together. The mixture of wastewater and microorganisms is known as **mixed liquor** and is then sent to **secondary clarifiers** where the activated sludge and other suspended material settle out. Part of the settled material is returned to the aeration basins to maintain the mass of activated sludge. The remainder of the sludge is sent to the sludge handling facilities.

After the secondary clarifier the wastewater will be disinfected (see the section on chlorine in the Water/Wastewater Chemistry section). The most common method of disinfection is chlorination. The sewage is moved to **chlorine contact chambers** where chlorine is added to kill harmful organisms. The sewage may undergo further treatment (tertiary treatment) or it may be discharged to the environment.

Although the activated sludge process, described above, is the most common in Ontario, other secondary treatment methods include aerated lagoons, trickling filters, and Rotating Biological Contactors (RBC). Like activated sludge process these methods depend upon the action of aerobic bacteria to break down the solids and BOD, and as such secondary treatment includes both physical and biological processes.

Secondary treatment typically removes 80-99% of the BOD and suspended solids.

SLUDGE DIGESTION

During the treatment processes sludges will be created which must be further treated before their final disposal. There are several different methods of treating sludge. The prime objective of all of these methods is to 'stabilize' the sludge so that there is a low oxygen demand. One of the more common methods is known as **anaerobic digestion**. In this method raw sludge which has settled in the primary and secondary clarifiers is "wasted" to anaerobic sludge **digesters**. It is held in the digesters for several weeks. During this period anaerobic bacteria (those which do not require dissolved oxygen) further break down the solids in the sludge to methane gas, carbon dioxide and inert solids. The gas may be further used as a fuel.

Sludge may also be treated in **aerobic digesters**. In this process the same types of microorganisms used in the activated sludge process will further breakdown the sludge. Eventually as food runs out the microorganisms will use their own stored body mass for energy, resulting in a stable final product.

The sludge which is removed from both anaerobic and aerobic digesters will often be further treated to remove water (**dewatering**). Often chemicals will be added to the sludge to assist in the dewatering process. Some common methods of dewatering include vacuum filtering, centrifuging, pressing, or drying beds. The final sludge may be spread on agricultural land or landfilled. Some facilities incinerate their sludge due to the high cost of transport to agricultural areas or high heavy metal content of the sludge. Sludge may also be composted to produce a valuable humus or soil conditioner.

TERTIARY TREATMENT

Some WWTPs also have tertiary processes to further treat the wastewater. There are many different types of tertiary processes but most involve physical/chemical processes. They include chemical precipitation, reverse osmosis, carbon adsorption, and filtration.

LAGOONS

Many smaller communities within Ontario do not use a conventional activated sludge process but instead operate **waste stabilization ponds (lagoons)**. Lagoons use natural physical and biological processes which occur in ponds to treat wastewater. Within the pond or lagoon solids settle to the bottom, while algae and bacteria process dissolved organic particles. Since raw wastewater usually enters the lagoons directly primary treatment is not required. Many different types of lagoons exist within Ontario, including **aerobic**, **aerated** and **facultative lagoons**. Aerobic lagoons are shallow (around 3 feet) and have a high concentration of dissolved oxygen. The oxygen is required for the aerobic bacteria to break down organic materials. Anaerobic lagoons, on the other hand, do not require dissolved oxygen in the wastewater for the bacteria to process the organic material. Before the effluent is released to the receiving stream it may be chlorinated to kill any pathogenic microorganisms.

Aerated lagoons are often used for high BOD loads, where the necessary area required for conventional lagoons is not available. Aerators are used to increase the oxygen content of the lagoon, in order to maximize aerobic bacterial action. The overall process is very similar to an conventional activated sludge system. Unlike most other lagoon systems, aerated lagoons may be operated with a continuous flow through of wastewater. (Other lagoons normally require a long retention time of wastewater, thereby requiring discharge of wastewater on a seasonal basis.)

Lagoons which combine the features of an aerobic and anaerobic lagoon can also be used. These are known as **facultative lagoons**. In these relatively deep ponds, the upper layer of water is aerobic, while the bottom layer is anaerobic. Algae will use the energy from the sun will convert the wastewater nutrients into cell mass. As the algae die the cells settle to the anaerobic zone where anaerobic bacteria break the cells down into methane, organic acids, hydrogen sulphide and carbon dioxide. Oxygen is added to the lagoon through wind action, the photosynthesis of algae, or by mechanical mixing. Facultative lagoons are very common in Ontario.

Lagoons can provide an economical alternative to conventional treatment, but require a large area of land and are less effective during the winter months. In some communities, with sufficiently large volume of wastewater, several ponds may be operated in parallel (several ponds operate independently) or in series (wastewater flows through several ponds before discharge).

WASTEWATER COLLECTION (WWT and WWC)

Wastewater collection facilities serve the purpose of transporting potentially hazardous materials in a safe manner for treatment and disposal. Wastes may include domestic sewage, industrial or commercial effluent. The waste is removed through sanitary sewers. Sewers which transport storm water runoff are called **storm sewers**. In older parts of some cities wastewater and storm runoff are carried by the same sewer, called a **combined sewer**. Cross connections between storm sewers and sanitary sewers should be avoided. Such connections will lead to the discharge of domestic and industrial waste into streams, rivers and lakes.

Operators of wastewater collection systems ensure that the flow of wastewater is not impeded. Operators will operate lift stations, flush and clean sewers, remove debris from sewers, repair sewer lines, and regulate flow.

Wastewater is originally collected by service connections from a home/industry into a **lateral** or **branch sewer**. **Main sewers** will transport waste from the branch sewers to larger trunk sewers. Wherever possible, the wastewater will be conveyed by gravity, but often **lift stations** will be necessary to raise the wastewater to a higher elevation. A lift station will normally contain two pumps and an alternative source of power. Without constant pumping ability wastewater may backup the sewer resulting in flooded basements. From a lift station wastewater is pumped through a **forcemain**, or pressurized pipe, to a treatment facility or to an elevated gravity sewer. Sewers pipes can commonly made of concrete, asbestos concrete (AC), polyvinyl chloride (PVC), or vitrified clay pipe.

Access to sewers are obtained through maintenance access points (manholes). Entry into a sewer is potentially dangerous, and should only be conducted by fully trained and equipped personnel. Provincial laws and regulations strictly regulate this activity.

One of the primary concerns of an operator of a wastewater collection system is the avoidance of sewer **surcharges**. A surcharge occurs when a sewer is hydraulically overloaded (i.e. too much wastewater is trying to flow through a sewer) resulting in sewage backing up the collection system. A surcharge can result in the flooding of basements or the release of sewage through maintenance access points onto roads. Some of the contributing factors of surcharging are the inflow of surface water into sewers and the **infiltration** of groundwater through cracks in the sewer wall. Infiltration of groundwater can be a serious problem resulting in the collection and treatment of much larger volumes of water than is required. **Exfiltration** (the flow of wastewater through cracks in the sewer wall into the ground) is another serious problem which can result in the contamination of groundwater.

Operators also must ensure that organic/inorganic material does not build up in the sewer. The easiest method of avoiding accumulation of material is to maintain a sufficiently high wastewater flow rate, or periods of high flow rates. Build up of organic materials may result in the production of **hydrogen sulphide** (H_2S) and other potentially dangerous gases. These gases not only produce an unpleasant odour, but can also cause corrosion of sewer lines. When operating wastewater collection facilities, operators must be aware of the potential toxic, or explosive hazards of these gases. Due to the corrosive nature of sewage gases, mains must be kept clear to allow sewage to move through the system quickly.

Occasionally a sewer pipe will require cleaning to remove blockages or constrictions. These blockages may be caused by greases, roots or accumulation of organic materials. Several methods of cleaning are used, including using high velocity jet cleaners, flushing, power rodders, or bucket machines.

EQUIPMENT (ALL)

PUMPS

Working as an operator, the most common machines you will encounter are pumps. It is important that you understand how each pump operates and the procedures for starting and stopping pumps. The consequences of operating pumps incorrectly can include system breakdown as well as component failure. The full consequence of starting or stopping any pump must be understood clearly before any action is taken. There are two basic types of pumps which are described below.

The **centrifugal pump** pressurizes water by "throwing it" at high speeds from the centre of the impeller to the outside. Such pumps should normally be started with the outlet closed. The various types of centrifugal pumps are normally described by their impeller shapes. Common types are radial vane, Francis vane, mixed flow and axial flow.

Positive displacement pumps operate by "pushing" the fluid mechanically. Such pumps are normally started with the suction valve and discharge valve open. Types of positive displacement pumps commonly encountered by operators include: screw, gear, piston, diaphragm and progressive cavity.

Packing glands prevent the pumped fluid from leaking from a pump. The seal also prevents air from entering the pump casing. Packing failure can be expensive if not noticed in time. Signs of wear include poor pump performance, flooding and rusted or damaged components. Mechanical seals which use smooth contact surfaces to seal the fluid are also common.

PIPES

Water and wastewater transportation systems can use cast iron pipe, ductile iron pipe, steel and reinforced concrete pipe, asbestos cement and plastic pipes (PVC, PE, ABS). New materials and compositions are constantly being developed. The most common pipe used in water systems generally has been the cast iron pipe, however PVC pipes are used increasingly, particularly in smaller pipes. The type of pipes used in a system depend on a combination of factors such as economy (material and installation), surrounding soil, strength, and anticipated life of the pipe material.

VALVES

Valves are used to stop or control the flow and pressure of a liquid or gas in a pipe. Many different types of valves are used in water/wastewater systems. These include gate valves, globe valves, butterfly valves, check valves, eccentric valves, air and vacuum relief valves. Each valve has a specific use. For example gate valves are used to completely stop the flow of liquid or gas. Globe valves and butterfly valves, on the other hand, can be used to control the amount of flow or pressure through the pipe (i.e. it can be set in between fully open and fully closed). Check valves are used to ensure that the liquid or gas can only travel in one direction in the pipe. Air and vacuum relief valves are used to release or admit air into a piping system.

CONTROL AND INSTRUMENTATION

Operators routinely monitor and control the flow of water/wastewater in their systems. An operator's efficiency depends on his/her ability to understand measurement and control devices. A measurement is a comparison between the process variable (i.e. pressure) and an acceptable standard. Water/wastewater facilities have a wide assortment of measuring or metering devices, including flow measurement (discussed above), temperature, and pressure. Control devices are used to change the processes within the system, if a certain condition exists. For example, a flow measuring devices will measure the rate of flow of water within a pipe and send an electronic signal to the controller. The controller will compare this rate of flow with the desired rate of flow for the pipe. If the rate of flow is beyond the acceptable range the controller will send an electronic signal to a valve. The valve in turn will either open or close in order for the desired rate of flow to be achieved. This type of system is known as a "feedback loop". The same principle is used to control your house's temperature with a thermostat.

CROSS CONNECTION CONTROL

Cross connection is a serious hazard. Operators should be aware of the problem of cross connection and how to prevent it. A cross connection is any connection to a potable water system which can allow any solid, liquid, or gaseous substance(s) to enter the potable water system, contaminating the disinfected water. Contamination occurs by backflow, which is a reversal of flow within a potable water system.

Siphonic backflow is caused by a drop in or negative mains pressure. **Back pressure backflow** is caused through an unprotected connection to any equipment or device having a pressure higher than that available to the water main.

Backflow prevention includes any effective device, method or construction used to prevent backflow into a potable water system. For example, check valves contain a hinged disc or flap that opens automatically in the direction of liquid flow, but prevents backflow.

All outside taps on new residential buildings in Ontario must have a backflow valve attached to prevent syphoning of household chemicals such as pesticides.

SAFETY (ALL)

The most important knowledge required by inexperienced operators is that of safety. The person most responsible for your safety is yourself. New operators should be given an extensive safety briefing when starting work and they should question every activity where they are not sure of the safety procedures and risks. You should also know the location and use of all safety equipment such as eye wash fountains, first aid kits, self contained breathing apparatus (SCBA), fire extinguishers, Material Safety Data Sheets, etc.

Treatment plants or distribution/collection systems are potentially dangerous places to work. Physical injuries and body infections are a continuous threat. Explosions and asphyxiations from gases or oxygen deficiency may occur, if proper procedures are not followed. Although infrequent at any particular location, such accidents are an all too common occurrence in the industry. Indeed, in the municipal sector wastewater collection and treatment is the most dangerous job next to solid waste collection. These occupational hazards may be largely avoided by following safe practices and the use of safety equipment. It is too late to consider safety issues after an accident occurs.

Accident prevention is the result of careful analysis of a situation, the application of a few basic principles and knowledge of the hazards involved. It has been said that the "ABC" of accident prevention is "Always Be Careful". One must learn how to be careful and what to avoid.

The overall dangers of accidents are much the same whether in maintenance access points, pumping stations or treatment plants. These result from:

1) body infections,
2) physical injuries, and
3) dangerous noxious gases or vapours, oxygen deficiencies and hazardous chemicals.

Workers in wastewater treatment plants are exposed to the hazards of water-borne diseases, including Hepatitis, Typhoid Fever, Amoebic Dysentery, Infectious Jaundice and other infections. Tetanus and skin infections must also be guarded against. A majority of infections reach the body by way of the mouth, nose, eyes and ears. Therefore, washing your hands is a must before eating, smoking or using the washroom. It is generally a good policy never to put your hands above your collar when working with plant equipment. Wear protective gloves where possible.

It is important to use safety equipment only as it is meant to be used. Protect eyes and face when there is any possibility of injuries from hand tools, power tools, welding equipment, chemicals, etc. Feet must be protected with safety shoes to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc. Hard hats are required to prevent serious injuries in construction, excavation, electrical work, buildings with low pipes or in other work as directed by your supervisor. Gloves should be used whenever handling materials, sharp objects, chemicals or electrical equipment. Use SCBA when hazards such as chlorine, painting or dusty areas exist. Accidents due to falls can be protected against by using safety belts and scaffolds. Spills must be immediately cleaned up to avoid slips. Except for minor injuries, wounds should be treated by a doctor and reported for possible Worker's Compensation. All injuries on the job must be reported to Worker's Compensation, as required by law.

Hand tools are the cause of many accidents and injuries when improperly used and in unsafe condition. Therefore, use the right tool for the right job in the right way. Use protective safety equipment where there is a job hazard. Keep the work area clear of hazards, with plenty of working space for solid footing. Tools should be in good condition and used for the purpose which they were intended.

Electrical equipment is a common risk. When examining, working or repairing electrical equipment it is essential to lock out the control device. After these precautions have been taken, attach lock-out tags such as 'WORKERS ARE WORKING ON LINE.' Lock-out tags shall remain on the opened devices until removed by the worker whose name appears on the tag.

Each operator should have first hand knowledge of fire extinguishers, its ABC rating, point of contact and time of operation.

Sewers pose health risks, are smelly and physically dangerous. A particular problem is the accumulation of toxic or explosive gases such as hydrogen sulphide and methane respectively. It is illegal to enter a maintenance access point without testing for these gases and to ensure there is sufficient oxygen. Workers must also test for the presence of methane gas *before* removing a access cover to avoid any possibility of an explosion. There may also be a requirement to force ventilate the maintenance hole to ensure a safe working atmosphere, free of dangerous gases and with sufficient oxygen.

Confined spaces pose a special safety hazard for operational staff. A confined spaces may be defined as any space to which exit by an injured person would be difficult. A confined space may also be defined as any space which because of its construction, location or contents hazardous gases or a deficiency of oxygen may occur. Examples would include a sewers, personal access points (manholes), digesters, and below grade lift/pumping stations. Special training is provided to workers who must enter maintenance holes or other confined spaces. Personnel who have not undertaken this training should not enter into a confined space.

Chlorine safety is detailed under the general heading of chlorine.

Safety in the work place is governed by the Ontario Health and Safety Act and its applicable regulations. These regulations should be explained to you by your supervisor. It is important to note that these regulations place demands on both you, your supervisor and your employer. To violate these regulations can lead to heavy fines and/or imprisonment. The Act also gives workers the right to refuse to do work if he/she has reasonable grounds that the work is dangerous. In such an event the worker must notify the supervisor immediately and remain on the job until an investigation is complete.

APPENDIX A:

<u>CERTIFICATION FACT SHEET : Number 2</u> **MARCH 1994**

TOPIC: OPERATOR-IN-TRAINING (OIT)

What is an operator-in-training licence?

Operator-in-training (OIT) is a type of operator's licence required by an operator with less than one year of operating experience. It is issued after an examination is passed.

An operator-in-training licence is the minimum requirement for all existing or new staff *before* they may perform any operational duties. This would include part time and seasonal staff.

Why does the operator-in-training designation exist?

Under the law all personnel performing operational duties *must* be licenced. The operator-in-training designation was created to allow new operators to gain the necessary one year experience and process knowledge to enable them to obtain a Class I licence. The operator-in-training examination encourages the new operator to review basic processes within a facility, and tests for basic knowledge of mathematics and applied science. In addition, people seeking employment in the water/wastewater field may demonstrate their competence to prospective employers by taking the OIT examination. **The OIT is also required by all current operators who missed the February 1, 1994 grandfathering deadline and are not currently licenced.**

What can an operator-in-training do?

An operator-in-training is a fully licenced operator. All the duties which a licenced operator may perform can be done by an OIT. Operators-in-training may also be designated as an operator-in-charge.

An OIT *may not* be an operator with overall responsibility or a backup for this person.

An owner or supervisor must carefully consider what duties an OIT are capable of performing. The OIT designation was created as a way for operators to gain experience and knowledge so that they may write the Class I examination. It was not designed to by-pass the regular Certification process. Owners, supervisors or operators-in-overall responsibility are responsible to ensure that a facility is properly staffed with personnel properly trained and experienced to perform their duties.

How do I become an operator-in-training?

To become an OIT, the operator is required to receive 70% on the operator-in-training examination. In addition the operator is required to have completed grade 12 or its equivalent.

Until August 31 1994 operators who were employed by February 1 1994, will have the grade 12 requirement waived.

An OIT licence may also be obtained by passing a Class I Certification examination. However, this process is slower and usually cannot be completed at the employee's workplace.

What about the operator-in-training examination?

The operator-in-training examination is designed to test a candidates basic knowledge on applied water/wastewater technology and basic mathematical skills. It is expected that new employees will be able to master the subject material within a week on the job, or through review of study materials.

There is a separate examination for each type of facility (i.e. water treatment, wastewater treatment, water distribution, wastewater collection). The examination consists of a core of 43 multiple choice questions which are the same for each type of examination. The topics include: basic and applied mathematics, basic and applied science, basic operating procedures, safety and legislation/responsibilities. In addition, 7 questions specific to the type of facility are included. If an operator requires a licence for more than one type of facility, they must write the core questions once, plus each specific facility questions.

The operator-in-training examination may be administered by a supervisor at a facility. These examinations may also be written on the regular Ministry Certification examination dates, at the Brampton Training Centre or other examination locations across the province. Contact the Certification Office for further details concerning the exam locations.

The Ministry of Environment and Energy will provide OIT candidates with specifically designed study material and examination "need to know" at a minimal cost. Although this material is not presently available, it should be ready for distribution by July 1994.
The operator may write the examination as many times as required to be successful, but no more often than once per week.

What is the cost of an operator-in-training licence?

There is no cost for the operator-in-training examination or licence. Presently there is no limit to the number of years an operator may maintain an OIT licence. It is expected that in the future an OIT will be charged a fee if he/she has not obtained a Class I licence after a number of years.

How do I apply for an operator-in-training?

An owner or operator may apply to write an OIT examination by contacting the Certification Office:

Ontario Environmental Training Consortium
7510 Farmhouse Court
Brampton, Ontario
L6T 5N1
FAX: 905-456-2246
PHONE: 905-456-0266 ➡ dial "2" for the Certification Section

Ministry of Environment and Energy
Ontario

PLEASE POST AT EACH FACILITY

APPENDIX B:

Ontario Water and Wastewater Operator Certification Program
Operator-In-Training Examination
"Need-To-Know"

1. **Basic and Applied Mathematics** ***(20-25% content on OIT examination)***
   - 1.1 Perform addition, subtraction, multiplication and division of whole numbers, fractions, decimals and percentages
   - 1.2 Express numbers in scientific notation
   - 1.3 Using conventional formulas, solve for:
     - Direct and inverse proportions
     - Area of rectangles, triangles, and circles
     - Surface area of cylinders
     - Volume of rectangular solids, prisms, cylinders, cones and spheres
     - Flow/pumping rate
   - 1.4 Define and use metric prefixes
   - 1.5 Using conversion references, convert from Imperial to metric measurements and vice-versa
   - 1.6 Interpret graphs and tables

2. **Basic and Applied Science** ***(20-25%)***
   - 2.1 Define concepts in basic chemistry
   - 2.2 Identify and describe chemicals used in water/wastewater treatment
   - 2.3 Define and describe the significance of basic water/wastewater treatment chemistry
   - 2.4 Define and describe the significance of basic concepts in microbiology
   - 2.5 Define basic electrical concepts
   - 2.6 Define basic hydraulic concepts

3. **Operating Procedures** ***(30-35%)***
   - 3.1 Describe the purpose of water/wastewater treatment
   - 3.2 Describe general processes/process control in water treatment/distribution, wastewater treatment/collection
   - 3.3 Identify equipment/materials used in water treatment/distribution, wastewater treatment/collection

4. **Safety** ***(15-20%)***
   - 4.1 Identify basic categories of safety hazards and basic safety procedures including:
     - Personal hygiene
     - Personal safety procedures
     - Fire/electrical safety procedures
     - WHMIS

5. **Legislation** ***(5-10%)***
   - 5.1 Describe relevant regulations and acts

APPENDIX C: REFERENCES

The following references are among those useful for operators studying for the Operator-in-Training and Class 1 Certification Examinations. Telephone numbers for ordering these resources are listed. Some of these resources are available through the Certification Office at (905) 456-0266 ext 332. In addition the Certification Office produces a document entitled *"Education & Certification Resource Guide For Water & Wastewater Utility Operators"*. This booklet lists a variety of study guides and training resources available to operators.

BASIC MATHEMATICS

Independent Learning Centre: (416) 965-2657

Secondary School Credit Courses

Western Canada Water/Wastewater Association: (403) 259-4041

Alberta Water and Wastewater Operators Level 1 Manual, $60

WATER AND WASTEWATER OPERATION

California State University, Sacramento: (916) 278-6142 or 6366

Water Treatment Plant Operation, Volume 1, $30 US

Water Distribution System Operation and Maintenance, $20 US

Operation of Wastewater Treatment Plants, Volume 1, $20 US

Operation and Maintenance of Wastewater Collection Systems, Volume 1, $20 US

Western Canada Water/Wastewater Association: (403) 259-4041

Alberta Water and Wastewater Operators Level 1 Manual, $60

SAMPLE EXAMINATION QUESTIONS

American Water Works Association (AWWA): 1-800-926-7337

Operator Certification Study Guide, Water Treatment/Water Distribution, $40

Water Environment Federation (WEF): (703) 684-2400

Certification Study Guide for Wastewater Treatment/Study Guide for Wastewater Collection System Personnel, $40

APPENDIX D:

CONVERSION FACTORS -- CANADIAN ABC EXAMINATION

To the left are the SI units (Systeme International d'Unites) which, when multiplied by the conversion factors shown, are equal to the Imperial Measure units on the right of the table. The arrows next to each conversion factor show the direction of the conversions.

Length

mm	x 0.039 37 →	inches
	← x 25.4	
mm	x 3.28 x 10^{-3} →	feet
	← x 304.8	
cm	x 0.393 7 →	inches
	← x 2.54	
cm	x 0.032 8 →	feet
	← x 30.48	
m	x 39.37 →	inches
	← x 0.025 4	
m	x 3.281 →	feet
	← x 0.304 8	
km	x 3 280.84 →	feet
	← x 0.3048x 10^{-3}	
km	x 1 093.61 →	yards
	← x 9.144 x 10^{-4}	
km	x 0.621 4 →	miles
	← x 1.609	

Weight/Mass

g	x 2.205 x 10^{-3} →	pounds
	← x 453.59	
g	x 15.432 3 →	grains
	← x 0.064 799	
g	x 0.035 27 →	ounces
	← x 28.349 5	
mg	x 2.205 x 10^{-6} →	pounds
	← x 453 592.3	
mg	x 0.015 43 →	grains
	← x 64.799	
kg	x 2.204 6 →	pounds
	← x 0.453 6	

Area & Volume

m^2	x 10.763 9 →	square
	← x 0.092 9	feet
m^2	x 1.196 →	square
	← x 0.836 1	yards
m^2	x 2.471 x 10^{-4} →	acres
	← x 4046.9	
ha	x 2.471 →	acres
	← x 0.404 69	
cm^3	x 0.061 024 →	cubic
	← x 16.387	inches
m^3	x 35.315 →	cubic
	← x 0.028 32	feet
m^3	x 219.9 →	Imperial
	← x 4.546 x 10^{-3}	gallons
L	x 0.2199 →	Imperial
	← x 4.546	gallons
mL	x 219,969.4 →	Imperial
	← x 0.4346 x10^{-5}	gallons
m^3	x 0.2199 x10^{-3} →	million
	← x 4.546	Imp. gallons
US gallon	x 0.8327 →	Imperial
	← x 1.2001	gallons

Work/Energy & Power

J	x 0.737 6 →	foot
	← x 1.356	pounds
kJ	x 0.947 8 →	B. T. U.
	← x 1.055	
kW	x 1.341 →	hp
	← x 0.745 7	(electric)

Pressure

Pa	x 0.145 x 10^{-3} →	pounds per
	← 6.895 x 10^{-3}	square inch
kPa	x 0.145 →	pounds per
	← x 6.895	square inch
kPa	x 4.014 5 →	inches of
	← x 0.249	water column
kPa	x 0.101 97 →	inches of
	← x 9.807	water column

Flow Rates (volume / time)

L/s	x 13.198 5 → ← x 0.075 84	gallons (Imperial) per minute
L/s	x 0.035 3 → ← x 28.316	cubic feet per second
L/s	x 2.118 9 → ← x 0.471 9	cubic feet per minute
L/s	x 127.134 → ← x 7.8650 x 10^{-3}	cubic feet per hour
L/s	x 0.019 005 6 → ← x 52.616	million (Imperial) gallons per day
L/d	x 0.219 975 → ← x 4.545 9	gallons (Imperial) per day
ML/d	x 0.219 975 → ← x 4.545 9	million gallons (Imperial) per day
m^3/d	x 219.975 → ← x 4.545 9 x 10^{-3}	gallons (Imperial) per day
m^3/d	x 0.219 97 x 10^{-3} → ← x 4.545 9 x 10^{3}	million gallons (Imperial) per day
m^3/s	x 19.005 6 → ← x 0.052 616	million gallons (Imperial) per day
m^3/s	x 2 119 → ← x 4.719 x 10^{-4}	cubic feet per minute
m^3/s	x 35.315 → ← x 0.283 2	cubic feet per second
$10^3 \cdot m^3/d$	x 490.596 → ← x 4.545 9	million gallons (Imperial) per day
m^3/min	x 17.70 → ← x 0.028 32	cubic feet per minute

Rates

kg/h	x 2.205 → ← x 0.453 6	pounds per hour
kg/d	x 2.205 → ← x 0.453 6	pounds per day
$g/m^2 \cdot s$	x 17.70 → ← x 0.056 51	pounds per day per square foot
$kg/m^2 \cdot h$	x 4.883 → ← x 0.204 8	pounds per hour per square foot
$kg/m^2 \cdot d$	x 0.204 8 → ← x 4.883	pounds per square foot per day
kg/ha·d	x 0.892 2 → ← x 1.121	pounds per acre per day
kg/ha·y	x 0.892 2 → ← x 1.121	pounds per acre per year
$kg/m^3 \cdot d$	x 0.062 43 → ← x 10.02	pounds per cubic foot per day
m/h	x 3.281 → ← x 0.304 8	feet per hour
$m^3/m^2 \cdot h$	x 3.281 → ← x 2.0385 x 10^{-3}	gallons (Imperial) per day per square foot
$m^3/m^2 \cdot h$	x 20.441 5 → ← x 0.304 8	cubic feet per hour per square foot
$m^3/m^2 \cdot d$	x 16.02 → ← x 0.048 92	gallons (Imperial) per day per square foot
m^3/kg	x 35.315 → ← x 0.062 43	cubic feet per pound

APPENDIX E:

FORMULAS - Operator-in-Training Examination

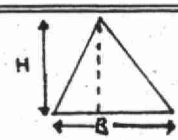
AREAS

Triangle

Area $= \frac{1}{2}$ BxH

B = length of base

H = height of triangle

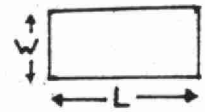


Rectangle

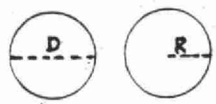
Area = L x W

L = length of rectangle

W = width of rectangle



Circle Area $= \pi R^2$ or $\frac{\pi D^2}{4}$



π = 3.1416

R = radius

D = diameter

VOLUMES

Rectangular tank

Volume = area of base x H

or V = L x W x H

L = length of ractangle

W = width of rectangle

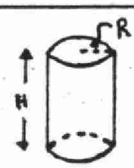
H = height of rectangle

Cylindrical tank

Volume = area of base x H

or V = $\pi R^2 \times H$

or V = $\frac{\pi D^2}{4} \times H$



R = radius of base

D = diameter of base

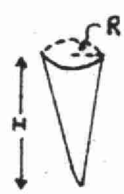
H =height of cylinder

Cone

Volume = 1/3 area of base x H

or V = $1/3 \pi R^2 \times H$

or V = $1/3\pi \frac{D^2}{4} \times H = \frac{1}{12} \pi D^2 \times H$



R = radius of base

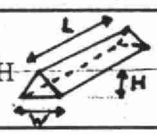
D = diameter of base

H = height of cone from base to apex

Prism

Volume = $\frac{1}{2}$ area of rectangular base x H

or V = $\frac{1}{2}$ L x W x H



L = length of rectangular base

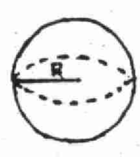
W = width of rectangular base

H = heigh tfrom base to apex

Sphere (ball)

Volume = $\frac{4\pi R^3}{3}$

or V = $\frac{4}{3} \pi \frac{D^3}{8} = \frac{1}{6} \pi D^3$

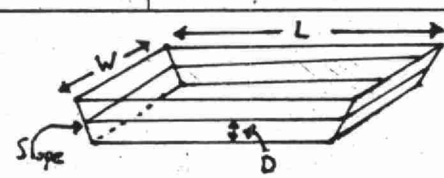


R = radius of sphere

D = diameter of sphere

Lagoon

Approx. Volume = $\frac{W \times L + (W-2SD) \times (L-2SD) \times D}{2}$



W = width of lagoon

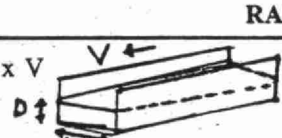
L = length of lagoon

S = slope (ratio of horizontal to vertical distances on the interior sides of lagoon example 3:1, slope is taken as 3)

D = depth of lagoon or depth of liquid in lagoon

RATE OF FLOW

Rate of flow (m^3/s) = W x D x V



W = width of channel (m)

D = depth of liquid in channel (m)

V = velocity of the flow (m/s)

(2) Pipe

Rate of flow (m^3/s) = A x V

A = cross sectional area (m^2)

V = velocity (m/s)

APPENDIX F: LIST OF THE ELEMENTS

Name	Symbol	Atomic Number	Atomic Weight	Name	Symbol	Atomic Number	Atomic Weight	Name	Symbol	Atomic Number	Atomic Weight
Actinium	Ac	89	227	Gold	Au	79	196.967	Potassium	K	19	39.102
Aluminum	Al	13	26.9815	Hafnium	Hf	72	178.49	Praseodymium	Pr	59	140.907
Americium	Am	95	243	Helium	He	2	4.0026	Promethium	Pm	61	147
Antimony	Sb	51	121.75	Holmium	Ho	67	164.930	Protactinium	Pa	91	231
Argon	Ar	18	39.948	Hydrogen	H	1	1.00797	Radium	Ra	88	226
Arsenic	As	33	74.9216	Indium	In	49	114.82	Radon	Rn	86	222
Astatine	At	85	210	Iodine	I	53	126.9044	Rhenium	Re	75	186.2
Barium	Ba	56	137.34	Iridium	Ir	77	192.2	Rhodium	Rh	45	102.905
Berkelium	Bk	97	249	Iron	Fe	26	55.847	Rubidium	Rb	37	85.47
Beryllium	Be	4	9.0122	Krypton	Kr	36	83.80	Ruthenium	Ru	44	101.07
Bismuth	Bi	83	208.980	Lanthanum	La	57	138.91	Samarium	Sm	62	150.36
Boron	B	5	10.811	Lawrencium	Lw	103	257	Scandium	Sc	21	44.956
Bromine	Br	35	79.909	Lead	Pb	82	207.1	Selenium	Se	34	78.96
Cadmium	Cd	48	112.40	Lithium	Li	3	6.939	Silicon	Si	14	28.086
Calcium	Ca	20	40.08	Lutetium	Lu	71	174.97	Silver	Ag	47	107.868
Californium	Cf	98	251	Magnesium	Mg	12	24.312	Sodium	Na	11	22.9898
Carbon	C	6	12.01115	Manganese	Mn	25	54.9380	Strontium	Sr	38	87.62
Cerium	Ce	58	140.12	Mendelevium	Md	101	256	Sulphur	S	16	32.064
Cesium	Cs	55	132.905	Mercury	Hg	80	200.59	Tantalum	Ta	73	180.948
Chlorine	Cl	17	35.453	Molybdenum	Mo	42	95.94	Technetium	Tc	43	99
Chromium	Cr	24	51.996	Neodymium	Nd	60	144.24	Tellurium	Te	52	127.60
Cobalt	Co	27	58.9332	Neon	Ne	10	20.183	Terbium	Tb	65	158.924
Copper	Cu	29	63.546	Neptunium	Np	93	237	Thallium	Tl	81	204.37
Curium	Cm	96	247	Nickel	Ni	28	58.71	Thorium	Th	90	232.038
Dysprosium	Dy	66	162.50	Niobium	Nb	41	92.906	Thulium	Tm	69	168.934
Einsteinium	Es	99	254	Nitrogen	N	7	14.0067	Tin	Sn	50	118.69
Erbium	Er	68	167.26	Nobelium	No	102	253	Titanium	Ti	22	47.90
Europium	Eu	63	151.96	Osmium	Os	76	190.2	Tungsten	W	74	183.85
Fermium	Fm	100	253	Oxygen	O	8	15.9994	Uranium	U	92	238.03
Fluorine	F	9	18.9984	Palladium	Pd	46	106.4	Vanadium	V	23	50.942
Francium	Fr	87	223	Phosphorus	P	15	30.9738	Xenon	Xe	54	131.30
Gadolinium	Gd	64	157.25	Platinum	Pt	78	195.09	Ytterbium	Yb	70	173.04
Gallium	Ga	31	69.72	Plutonium	Pu	94	242	Yttrium	Y	39	88.905
Germanium	Ge	32	72.59	Polonium	Po	84	210	Zinc	Zn	30	65.37
								Zirconium	Zr	40	91.22

APPENDIX G: HELPFUL HINTS FOR STUDYING

Effective study demands concentration. The ability to concentrate is largely determined by the individual's surroundings and physical condition. Being absorbed in study is being oblivious to everything else. Learning to concentrate is learning to overcome distractions.

Many distractions are best dealt with by elimination. The student who wants to do concentrated work can best begin by doing away with all unnecessary disturbances. A few important suggestions follow:

FAVOURABLE CONDITIONS FOR CONCENTRATION

1. Study in a quiet room free of any distractions such as TV, radio, telephone and other household members.

2. Make sure the room is properly lighted, heated (68 - 70°C) and properly ventilated.

3. Arrange your chair and work to avoid strain and fatigue. Shift your position from time to time. Be comfortable, but avoid being too comfortable. It is very difficult to study when reclining on a couch or easy chair.

EFFECTIVE STUDY HABITS

When studying, as when doing business, it is important to have a plan of action. If the plan is consistently followed, study becomes a natural part of your day. A fixed program of study is one of the greatest aids to effective and efficient work.

1. Always study in the same place. Have a particular table and chair which are always used for study and intellectual work. Your mind will come to associate this place with studying.

2. Only study for two hours at a time. Research has shown that little benefit results from extended study time. If you want to study more than 2 hours in one day, take a break first. Go for a walk, exercise or just relax between study periods.

3. Try to study at the same time every day. Make sure it is a time when you can study uninterrupted. Everyone has their own preference, however try to follow some basic guidelines, such as: pick a time of day when you feel mentally alert and avoid times when there is a lot of activity around you.

EFFECTIVE READING METHODS

In order to gain the most out of your study time you must learn how to read quickly and effectively. Usually an assignment is best mastered by combining an initial rapid survey with a more careful and thoughtful second reading.

1. Think about the topic of study before beginning to read. Prepare your mind. Retire to your area of study and sit quietly and concentrate on the topic at hand.

2. Be acquainted with the reading at the onset. Gain a first impression of the book by noting the title, section headings and manner of presentation. Decide what you expect to achieve.

3. Read through rapidly at first. This technique will give you a good background understanding without bogging you down with too many of the details.

4. Read through a second time. This time read more slowly, thoroughly and thoughtfully paying attention to more detail. Really concentrate on the meaning of what you are reading.

5. Make note of important points in your reading; highlight your book or make summary notes to use for your review.

6. Review the examination objectives (need-to-know). At the completion of a section, make sure you can answer all the questions related to the objectives of that section.

7. Complete each section thoroughly. Before moving on to the section be sure you have fully understood all the material covered in the previous section. Sections often build on each other, making it difficult to move forward without a thorough understanding.

CRAMMING AND EXAMINATIONS

Cramming may be good or bad, depending on what is meant by it. If it refers to feverish last minute efforts to memorize masses of previously unstudied material, it is harmful. It only serves to introduce fragments of knowledge that are quickly forgotten.

If cramming is interpreted as meaning a strenuous review at the end of intensive study, it is highly recommended. You can refresh your memory by running over the main ideas that you covered. If you have summary notes, use these for review.

1. Review the main points, getting a skeleton view of the subject. You should avoid memorizing scattered details. Focus on the main ideas and how the details are organized within this context.

2. Give yourself plenty of time for reviewing to avoid last minute pressures. Begin at least a week or two before the examination. Leave only a few finishing touches for the day before the examination.

3. Review the objectives (need-to-know) for the examination. Think over the kinds of questions which will probably be asked, and plan how to answer them.

4. When the examination period comes, be well rested, and remain as calm and self-confident as possible.

ANSWERING MULTIPLE CHOICE QUESTIONS

Multiple choice questions consist of a statement and several options for the answer. Only one answer is correct. The other, incorrect, options are called distracters or decoys. The following techniques will increase your chances of doing well on a multiple choice examination.

1. Listen to the examination administrator's instructions and read the directions carefully.

2. Read each question all the way through before answering. Often times an individual may feel overly confident and jump to answer the question without completely understanding what is being asked. One word could make the difference to the whole meaning of the question.

3. Read the options all the way through.

4. Mark only one best answer. Often times more than one answer may seem appropriate, however mark the most appropriate.

5. After you read the questions and the options, spend no more than a few seconds puzzling over the question (unless it is a calculation).

6. If the answer does not come to you right away, mark the question and move on to the next.

7. When you have worked your way through the test, go back to the questions you have marked for reconsideration.

8. The second time, mark one option and move on.

9. Make sure to answer every question. There is no penalty for guessing.

10. Reserve time to go over you answers and make necessary changes.

11. Watch out for negative and extreme words. Whenever you find negative words such as "not" or "except" in the question, circle them so they will stand out. Make sure you take them into consideration when you choose your answer.

12. Foolish options are usually incorrect. They are often simply distractions.

13. Check for look alike answers. Test makers occasionally list two options that are alike except for one word. It is likely that one of the pair is correct -- however read the options carefully.

CALCULATION PROBLEMS

Calculation problems are an important, and often challenging, part of all Operator Certification Examinations. The following suggestions will help you to solve calculation questions.

1. Make a drawing or sketch to help visualize the problem.

2. Break complex problems down into sections that you may solve separately. Simplify questions whenever possible.

3. Convert to the units required in the answer.

4. Round all answers to the nearest significant figure. For example, 68.575122 kg can be rounded to 69 kg if your measurements are only accurate to the nearest kg.

5. Check that your decimal place is in the proper position.

6. Make sure that your answer makes sense. For example, if you determine the annual cost for coagulant in a 10 mgd plant is $800,000,000,000, something is obviously wrong.

APPENDIX H:
WATER/WASTEWATER FACILITY OPERATORS GLOSSARY

(Source - Glossary Water and Wastewater Control Engineering, Ingram et al, Published by AWWA et al, 1969)

As an Operator-In-Training you will be placed in an "environment" which has a language unto its own. It is important that you quickly become familiar with the terms which your more senior colleagues use. Listed below are some of the terms which are commonly used in your new career field.

ABS -	Customary abbreviation of sodium alkyl benzene sulphonate. It is used to make pipe.
absorption -	The taking up of one substance into the body of another.
acidic -	A solution with a pH less than seven (7).
acidity -	The quantitative capacity of aqueous solutions to react with hydroxy ions. It is measured by titration with a standard solution of a base to a specified end point. Usually expressed as milligrams per litre as calcium carbonate.
activated sludge -	Sludge floc produced in raw or settled wastewater by the growth of zoogloeal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.
adsorption -	The taking up of one substance at the surface of another.
aerobic -	Requiring, or not destroyed by, the presence of free elemental oxygen.
algae -	Comparatively simple plants, one- or many-celled, usually aquatic, and capable of by obtaining energy through photosynthesis.

alkaline - The condition of water, wastewater, or soil which contains a sufficient amount of alkali substances to raise the pH above 7.0.

anaerobic - Requiring, or not destroyed by, the absence of air or free (elemental) oxygen.

appurtenances - Machinery, appliances, or auxiliary structures attached to a main structure to enable it to function, but not considered an integral part of it.

autotrophic organisms - Bacteria which thrive by using inorganic materials for energy and growth.

backflow - A flow condition, induced by a differential in pressure, that causes the flow of water or other liquid into the distribution pipes of a potable water supply from any source or sources other than its intended source.

backflow - preventer A device for a water supply pipe to prevent the backflow of water into the water supply system from the connections on its outlet end.

basic data - Records of observations and measurements of physical facts, occurrences, and conditions, as they have occurred, excluding any material or information developed by means of computation or estimate. In the strictest sense, basic data include only the recorded notes of observations and measurements, although in general use it is taken to include computations or estimates necessary to present a clear statement of facts, occurrences, and conditions.

BOD - Biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. It is a standard test used in assessing wastewater organic strength.

buffer - A solution containing a weak acid and its conjugate weak base whose pH changes only slightly on the addition of an acid or alkali.

bypass - An arrangement of pipes, conduits, gates and valves whereby the flow may be passed around a hydraulic structure or appurtenance.

Certificate of Approval - A document issued by the Ministry of Environment and Energy which approves an undertaking (such as the construction of alteration of a water or wastewater treatment facility). The C of A's purpose is to ensure the quality of the environment and human health are protected.

check valve - A valve which permits flow in one direction only.

chlorine residual -	The chlorine measured in water or wastewater, after application of chlorine.
COD -	Chemical oxygen demand. (see BOD above)
coliform -	A non pathogenic bacteria which indicates the possibility of pathogens.
concentration -	(1) The amount of a given substance dissolved in a unit volume of solution. (2) The process of increasing the dissolved solids per unit volume of solution, usually by evaporation of the liquid.
confined space -	A work area which has difficult egress and which may have toxic explosive gases or limited amounts of oxygen.
cross connection -	(1) A physical connection through which a supply of potable water could be contaminated or polluted. (2) A connection between a supervised potable water supply and an unsupervised supply of unknown potability.
crown -	The inside top of a sewer.
curb cock -	A shut off valve attached to a water service pipe from a water main to a building, installed near the curb, which may be operated by a valve key to start or stop flow in the water-supply lines of a building. Also called a curb stop.
facility -	Something designed, built, or installed to serve a specific function.
flushing -	(1) The removing of deposits of material which have lodged in conduits, sewers, or tanks because of inadequate velocity of flow. Water or wastewater is discharged into the conduits at such rates that the larger flow and higher velocity are sufficient to remove the material. (2) The release of water from hydrants to remove deposits from water pipes leading to the hydrant.
flume -	An open conduit of wood, masonry, or metal constructed on a grade and sometimes elevated. Sometimes called aqueduct.
force main -	A pressure pipe joining the pump discharge at a water or wastewater pumping station with a point of gravity flow.
gage (or gauge) -	(1) A device for indicating the magnitude or position of an element in specific units when such magnitude or position undergoes change; examples of such elements are the elevation of a water surface, the velocity of flowing water, the pressure of water, the amount of intensity of precipitation, and the depth of snowfall. (2) The act or operation of registering or measuring the magnitude or position of a thing when these characteristic are undergoing change. (3) The operation of determining the discharge in a waterway by using both discharge measurements and a record of stage.

hazardous work area -	A room or area in which hazardous materials are stored, such as the room in which chlorine cylinders are stored.
head -	The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid. (2) The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. It is used in various compound terms such as pressure head, velocity head, and loss of head. (3) The upper end of anything, as headworks. (4) The source of anything, as head water. (5) A comparatively high promontory with either a cliff or steep face extending into a large body of water, such as a sea or lake. An unnamed head is usually called a headland.
hydrant -	A device, connected to a water main and provided with the necessary valves and outlets, to which a fire hose may be attached for discharging water at a high rate for the purpose of extinguishing fires, washing down streets, or flushing out the water main. Also called fire plug. It is normally designed to drain itself when not in use.
hydrogen sulphide (H_2S) -	(1) Gas resulting from the decomposition of organic matter in waste water. (2) Gas produced during the digestion of sludge.
infiltration -	(1) The flow or movement of water through the interstices or pores of a soil or other porous medium. (2) The quantity of groundwater that leaks into a pipe through joints, porous walls, or breaks. (3) The absorption of liquid by the soil, wither as it falls as precipitation or from a stream flowing over the surface.
invert -	The floor, bottom, or lowest portion of the internal cross section of a closed conduit. Used particularly with reference to aqueducts, sewers, tunnels, and drains. Originally, it referred to the inverted arch which was used to form the bottom of a masonry-lined sewer.
isotopes -	Atoms with the same atomic number (same chemical element) but different atomic weights. Atoms of which the nuclei have the same number of protons but different numbers of neutrons.
jar test -	A laboratory procedure to determine the optimum coagulant dosage.
lateral - sewer	A sewer that discharges into a branch or other sewer and has no other common sewer tributary to it.
lift station -	A wastewater pumping station that lifts the wastewater to a higher elevation when the continuance of the sewer at reasonable slopes would involve excessive depths of trench, or that raises wastewater from area too low to drain into available sewers.
log -	A written record of events.

neutral - pH of 7.

nutrient - Phosphorus or nitrogen which promotes plant growth.

open switch - An electric switch in the "off" position so that there is no electrical connectivity.

packing gland - A device which retains packing around a rotating axle or shaft, this packing separates a fluid from the atmosphere -ie. it holds it within a pump

pathogens - Pathogenic or disease-producing organisms.

pH - The reciprocal of the logarithm of the hydrogen-ion concentration. The concentration is the weight of hydrogen ions, in grams, per litre of solution. Neutral water, for example, has a pH value of 7 and a hydrogen ion concentration of 10^{-7}.

precipitate - Insoluble settleable substance which is a product of a chemical reaction within a liquid.

priming - (1) The first filling with water of a canal, reservoir, or other structure built to contain water. (2) The action of starting the flow in a pump or siphon.

PVC - Polyvinyl chloride - A white water insoluble thermoplastic resin, used for making pipes.

sedimentation - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling.

slope - The inclination of gradient from the horizontal of a line or surface. The degree of inclination is usually expressed as a ration, such as 1:25, indication 1 unit rise in 25 units of horizontal distance; or in a decimal fraction (0.04); degrees (2 deg 18 min); or percent (4 percent). (2) In water supply and wastewater hydraulics, the inclination of the invert of a conduit expressed as a decimal, or as metres per stated length measured horizontally in metres.

sludge - (1) The accumulated solids separated from liquids, such as water or wastewater, during processing, or deposits on bottoms of streams or other bodies of water. (2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

spring line - The centre line of a sewer.

supernatant - The liquid standing above a sediment or precipitate.

suspended solids -	(1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.
tertiary - treatment	Treatment to remove nutrients from sewage before discharge to the environment.
thrust block -	A restraint to prevent separation of pressurized pipe systems at bends or ends.
trench -	(1) An excavation made for installing pipes, masonry walls, and for other purposes. A trench is distinguished from a ditch in that the opening is temporary and is eventually backfilled. (2) A relatively long but narrow structural or erosional feature of the earth's surface or the floor of the ocean.
trunk - sewer	A system of major sewers serving as transporting lines and not as local or lateral sewers.
turbidity -	(1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurement of light diffraction.
weir -	(1) A diversion dam. (2) A device that has a crest and some side containment of known geometric shape, such as a V, trapezoid, or rectangle, and is used to measure flow of liquid. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening.